Spatial mapping of the role of coastal habitats in mitigating flood risk in Wales

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Crynodeb Gweithredol

Gall cynefinoedd arfordirol chwarae rhan allweddol wrth liniaru'r risg o lifogydd a diogelu asedau economaidd. O ystyried pwysigrwydd cydnabyddedig twyni tywod, graean bras a morfeydd heli ar gyfer lleihau'r risg o lifogydd, mae angen nodi lleoliadau lle mae'r cynefinoedd hyn yn darparu budd o ran lleihau llifogydd er mwyn tynnu sylw at bwysigrwydd yr amddiffynfeydd naturiol hyn ac annog rheolaeth gynaliadwy arnynt.

Nod y prosiect oedd deall lleoliad, maint a budd cynefinoedd arfordirol ledled Cymru o ran y risg o lifogydd, a rhoi amcangyfrif o'r budd economaidd y maent yn ei ddarparu wrth liniaru llifogydd. Yr amcanion ar gyfer yr asesiad lefel uchel hwn oedd:

- Asesu 'gwerth swyddogaethol' cynefinoedd ar hyd arfordir Cymru ar gyfer lliniaru'r risg o lifogydd;
- Asesu'r gostyngiad posibl yn y difrod llifogydd y mae cynefinoedd yn ei ddarparu i asedau sy'n wynebu risg o lifogydd; a
- Nodi ardaloedd ar arfordir Cymru lle mae cynefinoedd o bosibl yn darparu budd hanfodol i liniaru'r risg o lifogydd a lleihau difrod.

Mae'r asesiad yn defnyddio data o'r prosiect Coastal Squeeze (Oaten et al., 2024) a nododd ardaloedd o dir isel y tu ôl i strwythurau anthropogenig neu nodweddion naturiol, y gallai'r llanw eu llenwi pe bai'r strwythur anthropogenig neu'r nodwedd naturiol yn cael ei dynnu oddi yno. Daeth yr ardaloedd hyn, ynghyd â'r ardaloedd cysylltiedig o flaendraeth, yn uned asesu ar gyfer budd cynefinoedd i'r risg o lifogydd, ac fe'u gelwir yn 'Unedau Arfordirol'.

Nodwyd y risg o lifogydd presennol, ehangder cynefinoedd ac asedau economaidd ym mhob Uned Arfordirol. Roedd budd y cynefinoedd eu hunain o ran y risg o lifogydd yn seiliedig ar bennu 'gwerth swyddogaethol' pob cynefin. I wneud hyn roedd angen nodi nodweddion allweddol fel lled ac uchder i asesu a yw'r cynefin yn darparu cyfraniad uchel iawn, uchel, canolig neu isel at leihau'r risg o lifogydd o'i gymharu â lleoliadau eraill. Yna cafodd gwerth swyddogaethol pob cynefin ei drosi'n sgôr a oedd yn adlewyrchu'r gostyngiad mewn difrod y mae'r cynefin yn ei ddarparu i'r Uned Arfordirol.

Defnyddiwyd dull cyfrifyddu ecosystemau i amcangyfrif y manteision y mae'r cynefinoedd yn eu darparu o ran amddiffyn rhag llifogydd. Mae cyfrifyddu ecosystemau yn broses o gasglu a chysylltu data ar faint ac ansawdd asedau ecosystemau i amcangyfrif eu lefel o ddarpariaeth gwasanaeth ecosystem; yn yr achos hwn, y gostyngiad mewn difrod llifogydd. Cyfunwyd yr wybodaeth hon â data ariannol i amcangyfrif y gwerth sy'n deillio o amddiffyn rhag llifogydd. Mesurwyd y buddion lliniaru llifogydd a ddarperir gan y cynefinoedd yn ôl yr amddiffyniad a roddir i eiddo (preswyl a masnachol), tir amaethyddol, a seilwaith ffyrdd a rheilffyrdd. Amcangyfrifwyd y manteision fel y gwahaniaeth rhwng senario llinell sylfaen, lle mae'r cynefinoedd yn bresennol (ac felly'n darparu buddion o ran lliniaru llifogydd), a senario lle nad yw'r asedau'n bresennol ac felly nad ydynt yn darparu buddion o ran lliniaru llifogydd.

Roedd cyfanswm o 380 o Unedau Arfordirol o amgylch arfordir Cymru ac roedd 285 ohonynt yn ffinio â thwyni tywod, graean bras, a/neu forfeydd heli. Roedd morfeydd heli yn bresennol mewn 62% o'r Unedau Arfordirol hyn, gyda thwyni a graean bras yn bresennol mewn 34% a 55% ohonynt, yn y drefn honno. Roedd gan gyfanswm o 23 o Unedau Arfordirol gynefinoedd yr ystyrid eu bod yn darparu gostyngiad o 100% mewn difrod llifogydd. Mae'r ardaloedd allweddol lle gwelodd Unedau Arfordirol ostyngiad mawr mewn sgoriau difrod yn cynnwys yr ardaloedd o amgylch Bae Caerfyrddin ac Aber Llwchwr, Bae Ceredigion ac o amgylch Ynys Môn.

Amcangyfrifir bod cyfanswm y buddion a ddarperir gan gynefinoedd arfordirol yn yr astudiaeth hon tua £36.1 miliwn (amcangyfrif canolog) yn 2025, a hynny'n bennaf oherwydd y difrod a osgowyd i eiddo (48%) ac, yn ail, yr amhariadau a osgowyd ar wasanaethau rheilffyrdd (37%). Mae'r ardaloedd allweddol lle nodwyd bod gan gynefinoedd y potensial i ddarparu budd sy'n bwysig yn economaidd o ran y risg o lifogydd ar draws yr holl asedau yn cynnwys ardaloedd ar hyd Aber Dyfrdwy, Ynys Môn/Afon Menai, gogledd Bae Caerfyrddin, Bae Abertawe, Caerdydd a Chasnewydd.

Mae nifer o ragdybiaethau a chyfyngiadau o fewn y dadansoddiad. Un o'r prif gyfyngiadau oedd pennu gwerthoedd swyddogaethol a diffinio'r gostyngiad canrannol mewn difrod y mae'r cynefinoedd yn ei ddarparu. Roedd y ddau'n seiliedig ar farn arbenigol fewnol CNC, wedi'i llywio gan y dystiolaeth sydd ar gael ar hyn o bryd o'r llenyddiaeth a'r astudiaethau hyd yma.

Er enghraifft, mae bylchau o hyd mewn gwybodaeth i bennu gwerthoedd mwy cywir ar gyfer y potensial i leihau'r risg o lifogydd, ac mae nifer o ffynonellau tystiolaeth yn dod o leoliadau daearyddol eraill (y DU ac yn ehangach). Felly mae'n annhebygol y bydd y gwerthoedd a ddefnyddiwyd yn gwbl gynrychioliadol o'r cynefinoedd ledled Cymru. Fodd bynnag, mae'r gwerthoedd yn caniatáu gwneud cymhariaeth gymharol o bwysigrwydd cynefinoedd o safbwynt y risg o lifogydd ledled Cymru. Nid yw ystod eang o ffactorau, gan gynnwys amodau hydrodynamig lleol, cyflwr cynefinoedd, a phresenoldeb amddiffynfeydd a wnaed gan ddyn, yn cael eu hystyried yn yr asesiad hwn ond byddent yn dylanwadu ar y gostyngiad yn y risg o lifogydd y mae'r cynefin yn ei ddarparu yn ymarferol. Felly, argymhellir bod asesiadau yn y dyfodol yn archwilio manteision o ran y risg o lifogydd fesul safle, gan ystyried gwybodaeth leol a data penodol i'r safle.

Mae yna hefyd sawl rhagdybiaeth allweddol sy'n sail i'r gwaith gwerthuso economaidd sy'n amrywio yn ôl math o asedau. Er bod hyn wedi caniatáu ymagwedd genedlaethol at y broses gyfrifyddu ecosystemau, mae lle i ymgorffori mwy o fanylion ynglŷn â'r gwahanol asedau mewn asesiadau yn y dyfodol. Gallai hyn, er enghraifft, gynnwys mwy o fanylion ar fath a maint eiddo, dyfnder llifogydd, hyd ac amseroedd rhybuddio, effeithiau dŵr hallt ar dir amaethyddol, a gwybodaeth fwy cywir am lwybrau dargyfeirio a chanslo trenau.

Executive summary

Coastal habitats can play a key role in mitigating the risk of flooding and safeguarding economic assets. Given the recognised importance of sand dunes, shingle and saltmarsh for reducing flood risk, there is a need to identify locations where these habitats provide a flood reduction benefit in order to highlight the importance of these natural defences and encourage their sustainable management.

The aim of the project was to understand the location, extent and flood risk benefit of coastal habitats around Wales and provide an estimate of the economic benefit they provide in mitigating flooding. The objectives for this high-level assessment were:

- Assess the ‘functional value’ of habitats along the Welsh coastline for mitigating flood risk;
- Assess the potential reduction in flood damages the habitats provide to assets at risk of flooding; and
- Identify areas on the Welsh coast where habitats potentially provide a vital benefit to mitigating flood risk and reducing damages.

The assessment draws upon data from a Coastal Squeeze project (Oaten et al., 2024) which identified areas of low-lying land behind anthropogenic structures or natural features, across which the tide could propagate if the anthropogenic structure or natural feature were removed. These areas, along with the associated foreshore areas became the unit of assessment for habitat flood risk benefit, termed ‘Coastal Units’.

The present day flood risk, habitat extents and economic assets within each Coastal Unit were identified. The flood risk benefit of the habitats themselves was based on determining the ‘functional value’ of each habitat. This required identifying key characteristics such as width and height to assess whether the habitat provides a very high, high, medium or low contribution to reducing flood risk relative to other locations. The functional value of each habitat was then converted into a score which reflected the reduction in damages the habitat provides to the Coastal Unit.

An ecosystem accounting approach was used to estimate the flood protection benefits that the habitats deliver. Ecosystem accounting is a process of compiling and linking data on the quantity and quality of ecosystem assets to estimate their level of ecosystem service provision; in this case, the reduction in flood damages. This information was combined with monetary data to estimate the value derived from flood protection. The flood mitigation benefits provided by the habitats were measured according to the protection provided to properties (residential and commercial), agricultural land, and road and rail infrastructure. The benefits were estimated as the difference between a baseline scenario, in which the habitats are present (and therefore providing flood mitigation benefits), to a scenario in which the assets are not present and therefore do not provide flood mitigation benefits.

In total, there were 380 Coastal Units around the Welsh coastline and 285 of them were fronted by sand dunes, shingle, and/or saltmarsh. Saltmarsh was present in 62% of these Coastal Units, with dunes and shingle present in 34% and 55%, respectively. A total of 23 Coastal Units had habitats which were deemed to provide a 100% reduction in flood damages. Key areas where Coastal Units had high reduction in damages scores include around Carmarthen Bay and the Loughor Estuary, Cardigan Bay and around Anglesey.

The total annual benefits provided by coastal habitats in this study are estimated to be in the order of £36.1 million (central estimate) in 2025, largely driven by the avoided

damages to properties (48%) and secondly by the avoided disruptions to rail services (37%). Some of the key areas where habitats have been identified as having the potential to provide an economically important flood risk benefit across all assets include Port Talbot, Newport, Neath, Swansea, Carmarthen Bay, and along the north coast of Wales.

There are a number of assumptions and limitations within the analysis. One of the main limitations was the determination of functional values and defining percentage reduction in damages provided by the habitats. Both were based on expert judgement from within NRW, informed by the evidence that is currently available from the literature and studies to date.

For example, there are still gaps in knowledge to determine more accurate values of flood risk reduction potential, and a number of evidence sources come from other geographical settings (UK and wider). The values used are therefore unlikely to be fully representative of the habitats across Wales but do allow for a relative comparison of the importance of habitats from a flood risk perspective across Wales to be made. A wide range of factors, including local hydrodynamic conditions, habitat condition, and presence of man-made defences, are not considered in this assessment but would influence the reduction in flood risk that a habitat provides in practice. It is therefore recommended that future assessments examine flood risk benefits on a site-by-site basis, factoring in local knowledge and site-specific data.

There are also several key assumptions underpinning the economic valuation work which vary by asset type. Whilst this has allowed for a national approach to the ecosystem accounting process, there is scope to incorporate more detail regarding the different assets in future assessments. This could, for example, include more detail on property type and size, flood depth, duration and warning times, the impacts of saline water on agricultural land, and more accurate information on diversion routes and rail cancellations.

1. Introduction

Coastal habitats, such as sand dunes, shingle and saltmarshes act as natural defences against flooding from the sea. These habitats can therefore play a key role in mitigating the risk of flooding and safeguarding communities, infrastructure, services and other assets.

There has been an increasing understanding in recent years of the mechanisms and processes by which coastal habitats provide flood and storm surge attenuation (Beynon-Davies, 2025). Coastal sand dunes, shingle and saltmarshes each possess different characteristics that contribute to their roles in mitigating flooding extent and severity along the coastline. Sand dunes and shingle are natural frontages which act as a physical barrier to waves and reduce wave and tidal energy. Saltmarshes act as a natural buffer to flooding due to their vegetated nature and gradual elevation which attenuate wave and tidal energy and reduce wave height.

The Welsh Government's National Strategy for Flood and Coastal Erosion Risk Management (Welsh Government, 2020) recognises the role that nature-based solutions and natural habitats can provide in reducing flood risk and supporting coastal zone adaptation and management. However, to date, their use in flood management projects and programmes has been limited.

In Wales, these habitats have experienced declines in extent and condition over the last few decades and future threats in the form of increased storm events and coastal squeeze from sea level rise have the potential to lead to further significant declines. Given their recognised importance for reducing flood risk (Welsh Government, 2020), there is a need to identify locations on the Welsh coast where these habitats provide a flood reduction benefit and determine the value of the economically important areas they protect. This improved understanding will highlight the importance of these natural defences, encourage their conservation and sustainable management, and encourage the consideration of natural habitats into flood management and coastal erosion management programmes.

The aim of the project was to understand the location, extent and flood risk benefit of coastal habitats around Wales that provide a flood risk benefit to low lying areas and provide an estimate of the economic benefit they provide in mitigating flooding. The key objectives for this high-level assessment were:

- Assess the functional value of habitats along the Welsh coastline for mitigating flood risk;
- Assess the potential reduction in flood damages the habitats provide to assets at risk of flooding; and
- Identify areas on the Welsh coast where habitats potentially provide a vital benefit to mitigating flood risk and reducing damages.

2. Methods

2.1. Overview

To assess the benefit coastal habitats around Wales provide in mitigating flood risk, five project phases were identified:

- Phase 1: Defining ‘Coastal Units’ – areas at risk of coastal flooding which will act as the units for assessment;
- Phase 2: Characterising Coastal Units;
- Phase 3: Determining the functional value of habitats;
- Phase 4: Determining the reduction in flood damages provided by the habitats; and
- Phase 5: Estimating the economic value of the reduction in flood damages provided by the coastal habitats.

To determine the project methodology, existing data layers were collated before defining the Coastal Units. This process is outlined below.

2.2. Data Collation

Input data utilised for this project were collated using publicly available data portals, licenced data provided by Natural Resources Wales, and the outputs from the Coastal Squeeze project (Oaten et al., 2024). Due to the national-level scale of the assessment, existing spatial data layers were used for the methodology; therefore, no manual digitisation or data layer creation was undertaken. All data were stored in an ArcGIS Pro geodatabase, and key information stored in an associated data catalogue. The table below (Table 1) provides the full list of input data with associated definitions to aid interpretation of the project methodology.

Table 1 Data input catalogue

Name	Source	Definition
Accommodation Space	Coastal Squeeze	Area of low-lying land behind an anthropogenic structure or natural feature
Assessment Unit Line	Coastal Squeeze	A continuous line along the coastline of Wales that represents different types of frontages
Digital Terrain Model (DTM)	Coastal Squeeze	A raster data layer showing the elevation of the ground surface/terrain in Wales
Flood Risk Assessment Wales	DataMapWales	A national assessment of flooding risk from rivers, the sea and surface water and small watercourses
Foreshore Area	Coastal Squeeze	Area seaward of the Assessment Unit line
Littoral Coarse Sediment	JNCC EUNIS L3 A2.1	Spatial extent of littoral coarse sediment in Wales
Marine Protected Areas (MPAs), Sites of Special Scientific Interest (SSSI), and Marine Conservation Zones (MCZ)	DataMapWales	Spatial data representing designated sites in Wales
National Coastal Erosion Risk Management (NCERM)	DataMapWales	Represents the spatial NCERM coastal baseline split into frontages which are defined as lengths of coast with consistent characteristics
National Receptor Dataset (NRD)	DataMapWales, licenced by Natural Resources Wales	Point data layer representing risk receptors, including residential and commercial property
OS Open Roads	Ordnance Survey Data Hub	High-level dataset of the road network

Name	Source	Definition
OS Open Zoomstack	Ordnance Survey Data Hub	Open vector basemap showing coverage of Great Britain
Predictive Agricultural Land Classification (ALC) Map 2	DataMapWales	Spatial data representing agricultural land grades
Saltmarsh Extent	Natural Resources Wales	Spatial extent of saltmarsh in Wales
Sand Dune Extent	Natural Resources Wales	Spatial extent of sand dunes in Wales
Shingle Extent	Natural Resources Wales	Spatial extent of vegetated shingle in Wales
Spatial Flood Defences with Standardised Attributes	Natural Resources Wales	Spatial data of flood defences that have been built to protect against flooding from both rivers and the sea
Tidal Layer	Coastal Squeeze	Defines the present-day MLWS, mean high water neaps (MHWN) and the HAT around the entire Welsh coastline

The use of these data layers for the analysis is described in the methodology below. As this was a national level assessment, a number of assumptions and limitations are associated with the approach used. These are mentioned throughout the methods section but are discussed in more detail in the ‘Next Steps and Recommendations’ section of the report.

2.3. Phase 1: Defining 'Coastal Units'

In order to evaluate the flood risk benefit of coastal habitats, areas with the potential to be flooded from the sea needed be identified first. The Coastal Squeeze project (Oaten et al., 2024) identified Accommodation Spaces, which are defined as areas of low-lying land behind an anthropogenic structure or natural feature, across which the tide could propagate if the anthropogenic structure or natural feature were removed.

These Accommodation Spaces are linked to Assessment Units, which form a continuous line along the coastline of Wales. Assessment Units can represent either a:

- Anthropogenic Structure (e.g. coastal defence or railway embankment);
- Natural Feature (e.g. beach crest / dunes ridge) which has low lying land behind;
- High Ground within an estuary; or
- Cliff along an open coast.

The Accommodation Space therefore encompasses the area landward of an Assessment Unit into which habitat could roll back and extends from present-day (2025) Mean Low Water Springs (MLWS) to Highest Astronomical Tide (HAT) plus 1 metre in 2155 (using UKCP2018, RCP 8.5 95%ile SLR allowance).

The Foreshore Area is the area seaward of the Assessment Unit line. Within estuaries, the seaward limit of the Foreshore Area is taken to be the centre line of the main channel running through the estuary, or a sub-branch of an estuary.

By grouping Accommodation Spaces and their associated Assessment Unit(s) and Foreshore Areas together, this defined the Coastal Units, which became the unit of assessment for determining the flood risk benefit of coastal habitats (Figure 2.1 and Figure 2.2). The Coastal Units and their distribution around the coast of Wales is shown in Figure 2.3.

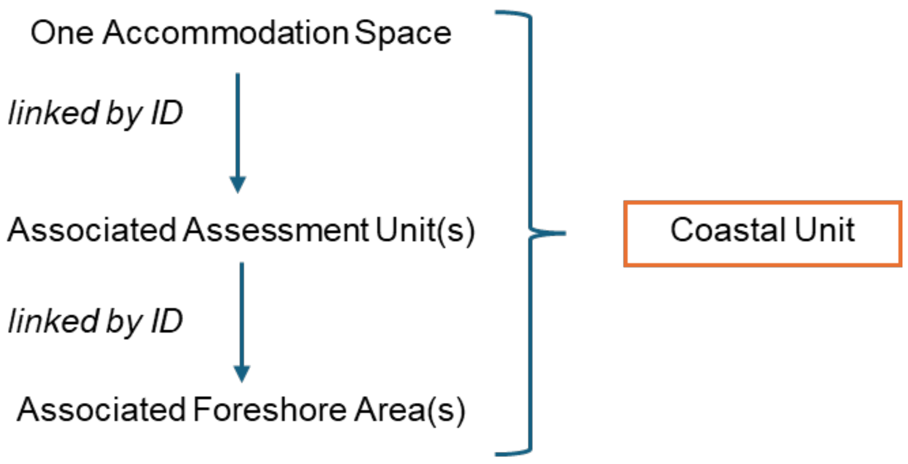


Figure 2.1 Data layers forming the Coastal Units

Figure 2.2 A section of the Welsh coastline showing the Assessment Unit line, Accommodation Space, and Foreshore Area

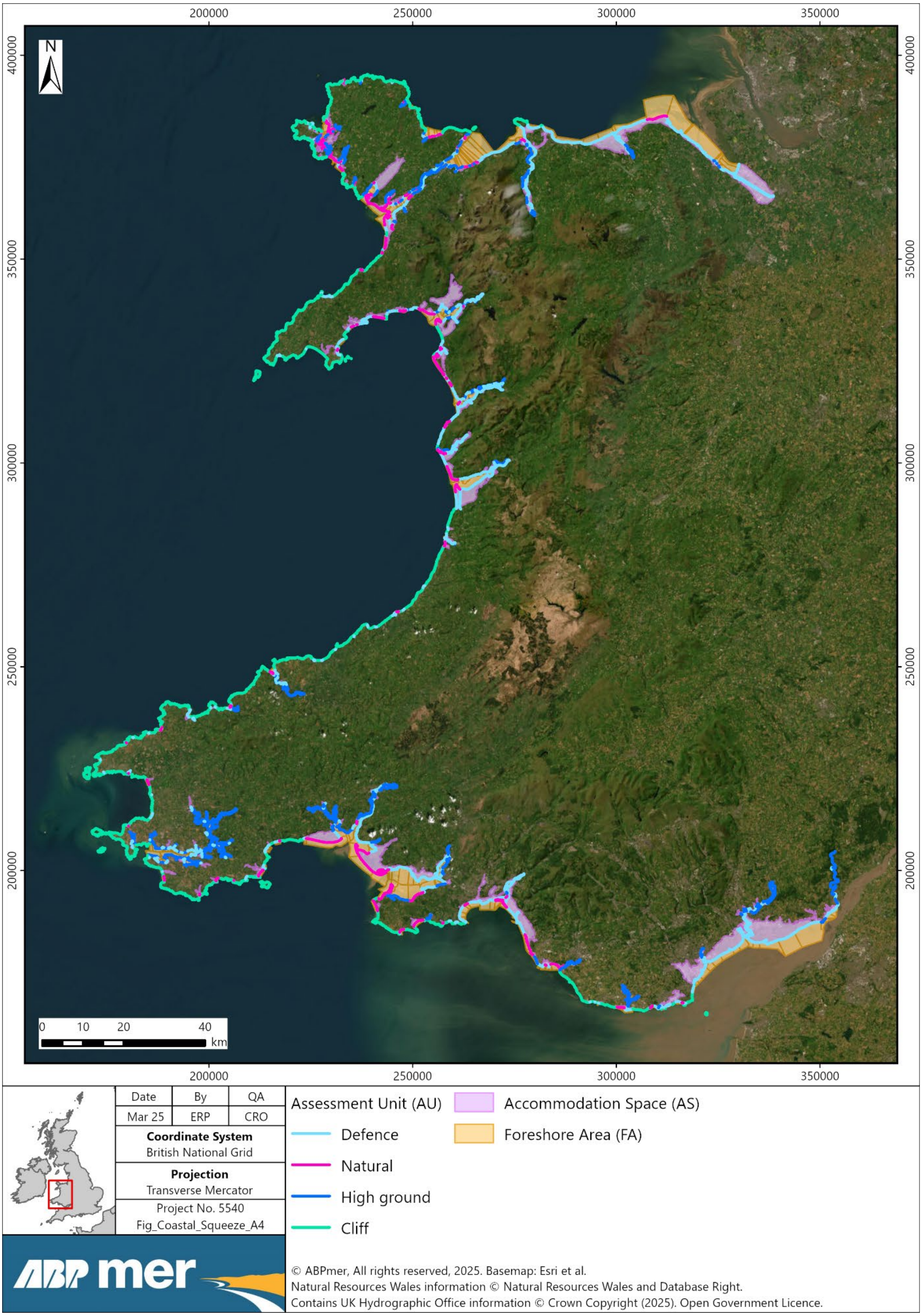


Figure 2.3 Accommodation Spaces, Assessment Units, and Foreshore Areas around the coast of Wales

2.4. Phase 2: Characterising of Coastal Units

2.4.1. Habitats

Once the Coastal Units had been derived, the extent of sand dunes, shingle and saltmarsh habitats within the boundaries of each Coastal Unit were determined using the following habitat layers (and see Figure 2.4a-c):

- Sand dune extent;
- Saltmarsh extent;
- Vegetated shingle extent; and
- Littoral coarse sediment extent.

The JNCC EUNIS L3 A2.1 littoral coarse sediment habitat data were joined to the NRW vegetated shingle extent to become the total shingle extent used for this analysis. A total of 62 shingle habitats were below HAT and whilst these habitats may contribute to wave energy dissipation, they do not provide a sufficient barrier to prevent flooding from the sea. As a result, they were not included in the assessment.

For each Coastal Unit, the length of the coastline fronted by each habitat was calculated to provide an estimate for the proportion of the coastline each habitat protects. To capture the lengths of coastline in an automated way, the Assessment Unit line was buffered at a set distance per habitat type. The buffer distances used were based on the approximate distances of a range of example habitats to the Assessment Unit line as measured within ArcGIS Pro. This resulted in the application of buffer distances of 30 m for dunes and shingle and 70 m for saltmarsh. As a result of this approach, three habitats within three Coastal Units were not captured by the assessment. However, on review, two of these habitats were a relatively large distance away from the coastline and hence the level of protection provided by them would require more detailed site specific consideration.

The total area of each habitat within the Coastal Unit was also obtained. The length and area of the habitat was then used to calculate an inferred width of each habitat within each Coastal Unit.

Height is a key characteristic regarding the effectiveness of dunes and shingle in mitigating flood risk. To determine the approximate heights of each dune and shingle habitat in a given Coastal Unit, the Tidal Layer and Digital Terrain Model (DTM) generated in the Coastal Squeeze project were utilised. The Tidal Layer defined the present-day MLWS, mean high water neaps (MHWN) and the HAT around the entire Welsh coastline. The DTM is a layer consisting of height contour data at 1 m resolution covering the entire Welsh coastline between the tidal levels for the present day MLWS to future (for the year 2155) HAT plus 1 metre. The DTM covers the entire space within each Coastal Unit. These layers were used to determine the height of dune and shingle habitats above HAT (i.e. height at which overtopping could occur and lead to flooding) within each Coastal Unit.

Height was not taken into account for saltmarsh, as saltmarsh do not provide a physical elevated defence to coastal flooding.

2.4.2. Current flood risk

For each Coastal Unit, areas at high, medium and low risk from flooding from the sea in the present day were identified using the Flood Risk Assessment Wales (FRAW) data layer (see Figure 2.4d and Figure 2.5). This layer was used to determine the flood risk to the different assets mentioned below. The FRAW data layer accounts for man-made flood defences in its assessment of flood risk. While no further adjustments for these defences are included in the methodology presented below, their influence may be incorporated into future assessments (see Section 4).

2.4.3. Assets

In order to quantify the economic benefit of the habitats, it was necessary to identify the assets in each flood risk zone within each Coastal Unit. The key assets used in this assessment included properties and infrastructure, agricultural land, road and rail. The data regarding each of these assets were obtained from the following data layers:

- National Receptor Dataset (NRD) 2023, Natural Resources Wales: risk receptors, including residential and commercial property, intended for flood and coastal erosion risk management projects;
- Predictive Agricultural Land Classification (ALC) Map 2, Welsh Government (Figure 2.6): spatial data representing land grades based on the principles of the Agricultural Land Classification System of England & Wales, and the Revised Guidelines & Criteria for Grading the Quality of Agricultural Land (MAFF 1988);
- OS Open Roads, Ordnance Survey: high-level dataset of the road network, from motorways to country lanes (Figure 2.7); and
- Rail lines from OS Open Zoomstack, Ordnance Survey (Figure 2.7).

Not every Coastal Unit has flood risk zones from FRAW within it, this is because the FRAW data layer represents present day risk of flooding from the sea, whereas the Accommodation Spaces represent flooding extent up to the year 2155. As a result, it was not possible to assess the economic benefit of the reduction in flood damages provided by habitats in the Coastal Units where risk of present-day flooding does not occur (see Section 2.7). Where this occurs, an assessment of the flood benefit habitats provide was still undertaken to highlight areas where habitats may provide a benefit under future scenarios.

2.4.4. Other variables

Lastly, the following data were captured per Coastal Unit to provide additional context for each study area:

- Short term (0-20 year) coastal erosion rates from National Coastal Erosion Risk Management (NCERM), Natural Resources Wales: an up-to-date benchmark dataset showing erosion rates for 0 to 20 years;
- Spatial Flood Defences with Standardised Attributes, Natural Resources Wales: provides spatial data of flood defences that have been built to protect against flooding from both rivers and the sea; and
- Marine Protected Areas (MPAs), Sites of Special Scientific Interest (SSSI), and Marine Conservation Zones (MCZ).

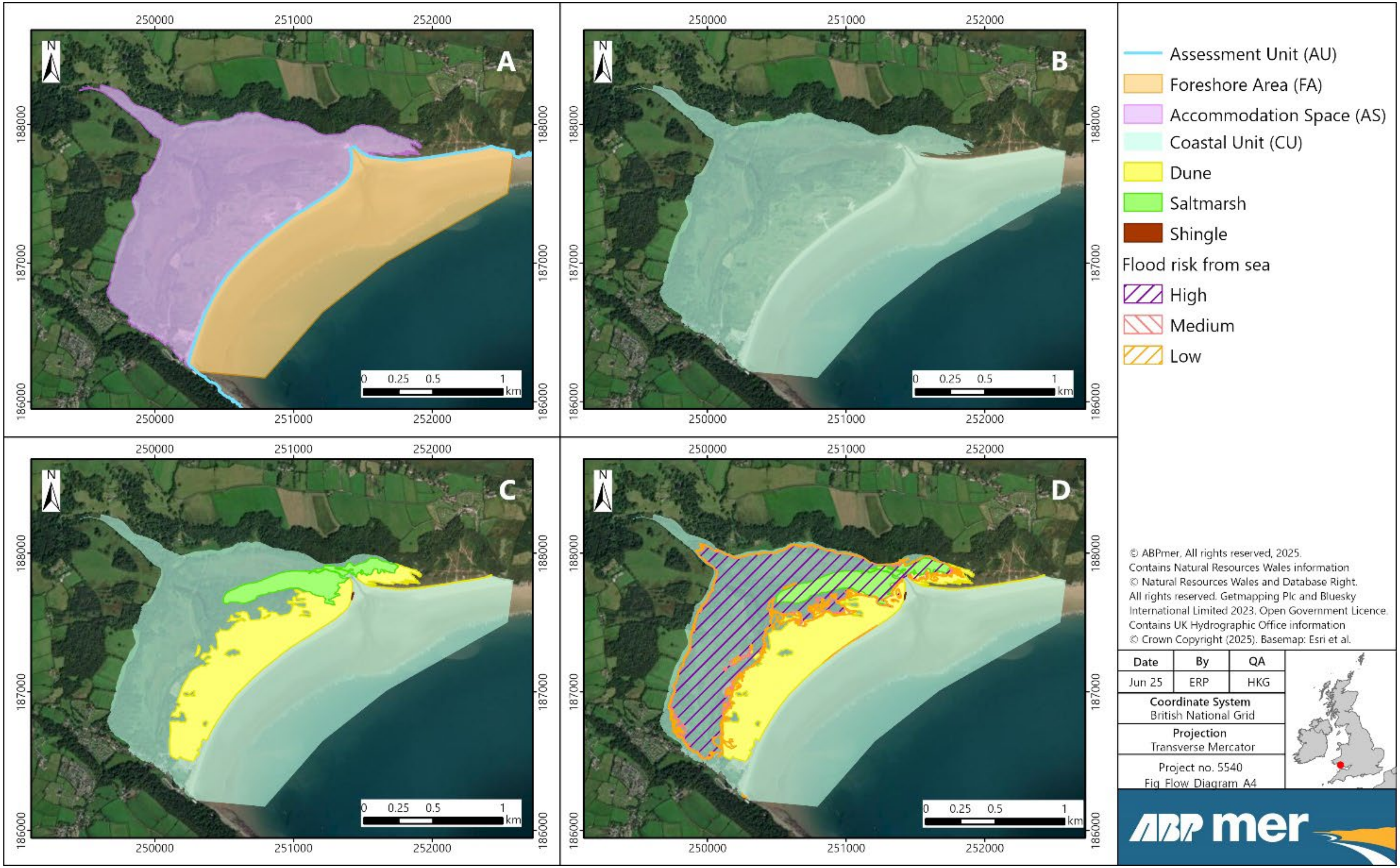


Figure 2.4 Process of defining Coastal Units and the habitats and flood risk areas within them: a) the assessment unit line, accommodation space and foreshore area , b) the coastal unit made from merging the layers in a), c) the various habitats within the coastal unit, d) the different flood risk bandings for the coastal unit.

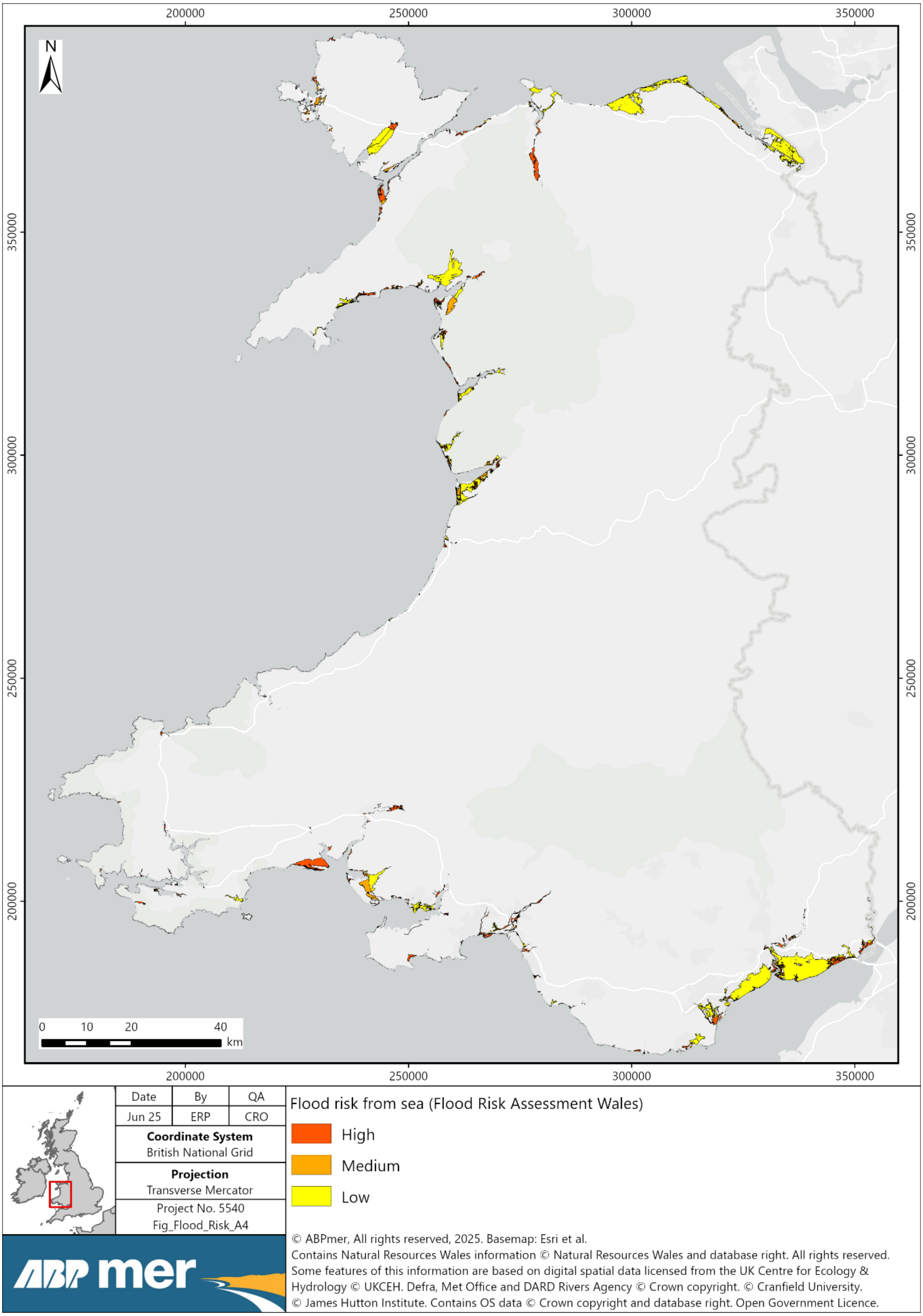


Figure 2.5 Flooding from the sea risk zones around the coastline of Wales (FRAW)

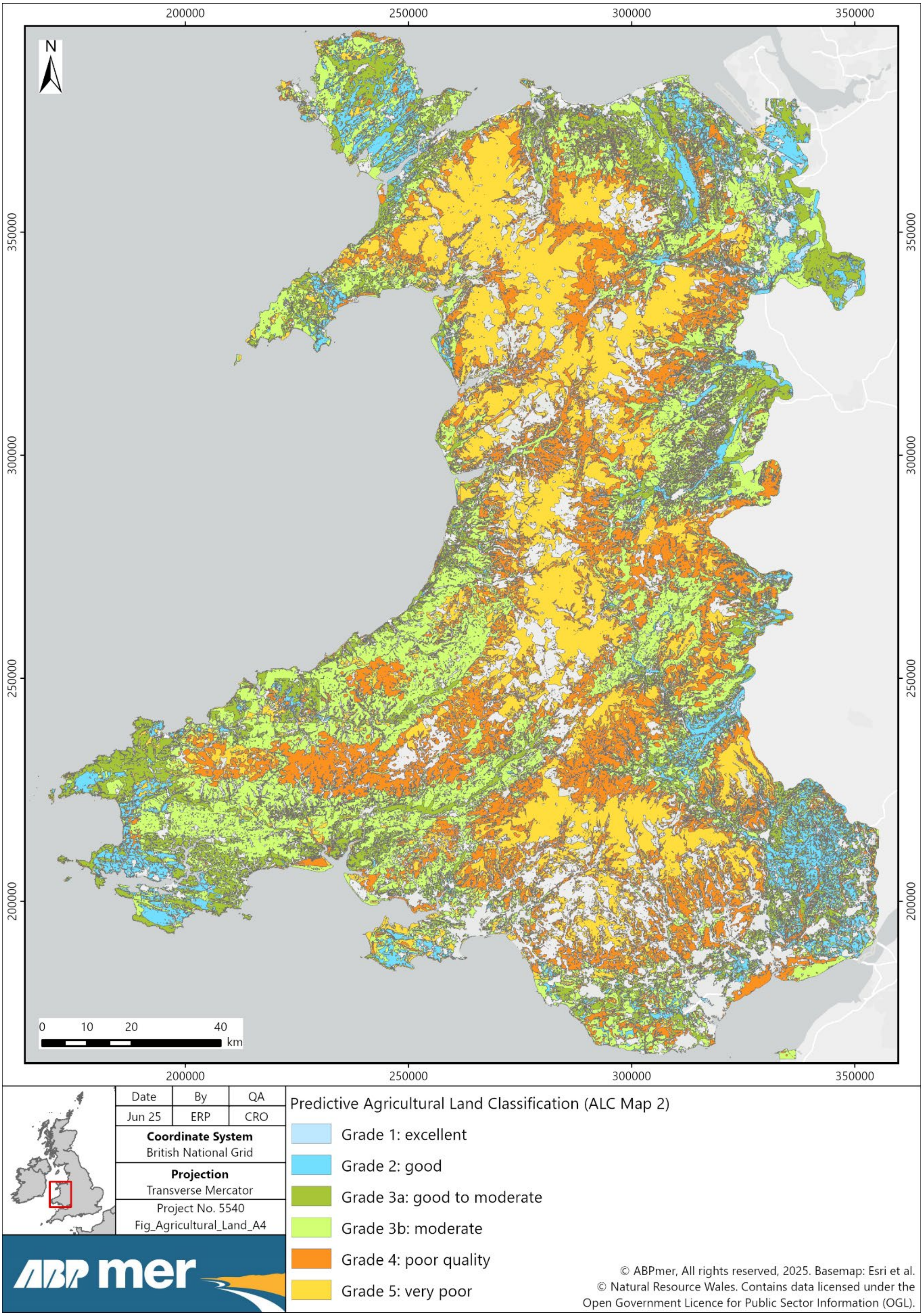


Figure 2.6 Agricultural land classification across Wales (ALC Map 2)

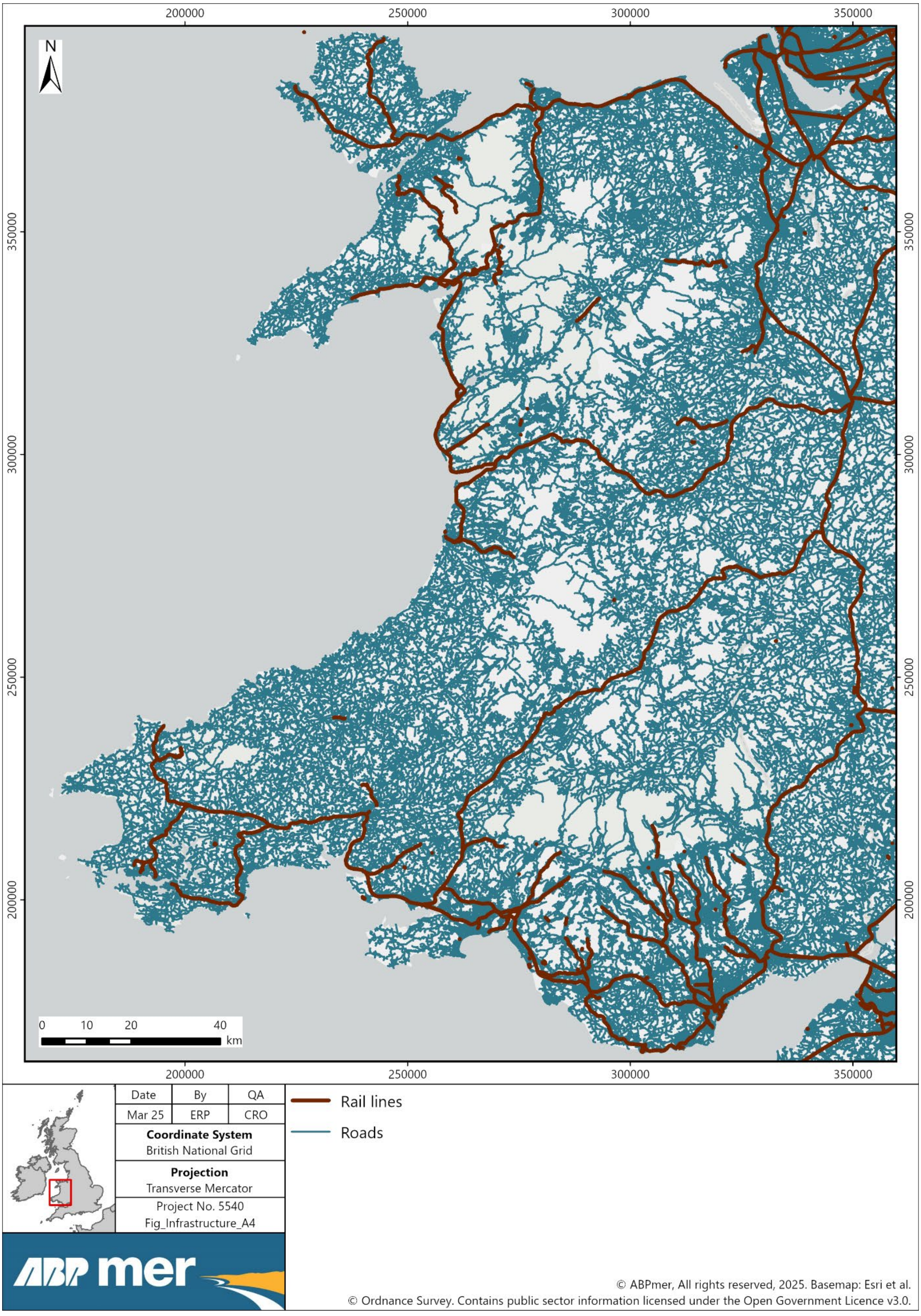


Figure 2.7 Roads and rail lines across Wales (Ordnance Survey)

2.5. Phase 3: Determining the functional value of habitats

For this assessment, it was necessary to determine the potential benefit provided by each habitat within a Coastal Unit in mitigating flooding. Hence, key characteristics of each habitat were used to categorise them based on whether they provide a very high, high, medium or low contribution to reducing flood risk. This was termed the 'functional value' of the habitat. The habitats mitigate flood risk in different ways, therefore, detail is provided below on how the functional value was obtained for each habitat type.

It is important to note that the values used to characterise the functional value of habitats were based on both expert judgement and, where available, key literature sources. These values were agreed with NRW and ultimately allow for a relative comparison of the functional value of habitats across Wales to be made. Typically, a wide range of factors not considered in this assessment will influence the reduction in flood risk that a habitat provides. Additionally, where values from the literature were used to inform this assessment, the studies were based on individual or a small number of Welsh and English sites where detailed information about the habitats were used. It is therefore uncertain how representative these site-specific values may be of other habitat sites around Wales. More information on the limitations and assumptions in this study is provided in the final section of this report.

2.5.1. Saltmarsh

The functional value of saltmarsh was based on the width of the marsh. Saltmarshes attenuate wave energy and reduce the height of waves as they approach the shore. Studies have found average wave attenuation to range from 80% - 99% over 160-180 m of saltmarsh, and a reduction in wave height by more than 87% (Möller et al., 1999; Möller & Spencer, 2002). It is worth nothing that reductions in wave energy or height are likely to be non-linear across the width of a saltmarsh, with the largest reductions likely occurring within the first few tens of metres (Möller & Spencer, 2002). However, for the purposes of this assessment, a wider saltmarsh was expected to attenuate a higher proportion of the wave energy over its width than a narrower saltmarsh.

In the absence of similar values for tidal attenuation, it was assumed that the attenuation of tidal and surge flows would exhibit a similar distribution to wave attenuation given both are also governed by enhanced friction.

The functional value categories for saltmarsh used in this assessment are shown in Table 2.

Table 2 Saltmarsh characteristics for determining functional value

Functional Value	Physical Description
Very High	>150 m width
High	50 – 150 m width
Medium	10 - 50 m width
Low	<10 m width

2.5.2. Dunes

The functional value for dunes was based on both width and height of the dune system. Sand dunes can act as a physical barrier to reduce wave and tidal energy but they are dynamic systems which undergo erosion and accretion following storm events. The maximum height and cross-sectional area of dune systems together with their interactions with maximum water levels are the main influences on their flood protection potential.

Functional values for dune systems were derived from Pye et al. (2017), who developed a classification system of a level of protection based on a general relationship relating dune crest level and width. These were adapted to focus only on heights above HAT as specific values of storm surge level and wave run-up level were not available on a national scale.

The functional value categories for dunes used in this assessment are shown in Table 3.

Table 3 Dune characteristics for determining functional value

Functional Value	Physical Description
Very High	> 5 m above HAT and > 100 m wide
High	> 5 m above HAT & < 100 m wide or 2-5 m above HAT and > 50 m wide
Medium	2-5 m above HAT & < 50 m wide or 1-2 m above HAT and > 20 m wide
Low	1-2 m above HAT < 20 m wide or < 1 above HAT and < 100 m wide

2.5.3. Shingle

Similar to dunes, shingle ridges can act as a barrier to flooding from the sea, and reduce wave and tidal energy. Pye et al. (2018) described the shingle crest elevation, width at mean high water springs (MHWS) elevation, and the elevation of the hinterland as key characteristics which contribute towards reducing flood risk. Data were not available on the width of the shingle at MHWS and hence functional value categories were based only on ridge height above HAT. Moreover, given that in many cases shingle consists of a single, narrow ridge, width was considered secondary to height for this habitat. The heights for high functional values were based on the heights required to protect against an approximately 1 in 200 year event at two shingle bank sites in Wales - Fairbourne and Newgale (Guthrie & Phernambucq, 2018). Recent work by Stokes et al. (2021) broadly supports this approach in terms of the overtopping levels for the most extreme storm events. It is important to acknowledge that these studies are informed by site specific data and are unlikely to represent all shingle banks along the Welsh coastline.

The functional value categories for shingle used in this assessment are shown in Table 4

Table 4 Shingle characteristics for determining functional value

Functional Value	Physical Description
Very High	>4 m above HAT
High	2-4 m above HAT
Medium	1-2 m above HAT
Low	<1 m above HAT

2.6. Phase 4: Determining the percentage reduction in flood damages provided by the habitats

After the functional values of the habitats in each Coastal Unit were derived, it was converted into a value equating to the percentage reduction in flood damages by the presence of that habitat. This reduction in flood damages was necessary to facilitate the assessment of the economic benefit the habitats provide in Phase 5. To obtain the percentage reduction in flood damages, three steps were taken:

1) A percentage reduction in flood damages was assigned to each habitat within a Coastal Unit based on its functional value;
2) The percentage reduction in flood damages for each habitat within a Coastal Unit was scaled by the length of the coastline fronted by the habitat; and
3) The scaled percentage reduction in damages for each habitat were summed (across all three habitats where they were present) to obtain an overall percentage reduction in flood damages for the Coastal Unit.

Further details on these steps are provided below. Again, it should be highlighted that expert judgement and available literature were used to assign percentage reduction in flood damage values for each habitat. Values were agreed with NRW who discussed the values and limitation with experts in the field. There is currently limited information in the literature on the contribution each habitat makes towards reducing damage to assets during a flooding event. However, the values used allow for a relative comparison to be made between habitats and Coastal Units around the Welsh coastline.

The first step required reduction in flood damage percentages to be determined. For this assessment, it was considered appropriate for the percentages to be dependent on habitat type as each habitat is likely to provide a different level of protection given their different characteristics.

The percentage reduction in flood damages were assigned to each habitat within a Coastal Unit based on the functional values derived in Phase 3. Dunes that had a very high functional value were considered to provide close to total protection to flooding due to it being extremely unlikely for water to overtop or breach the dune given its height and width. Hence it was expected that these dunes provided a 100% reduction in damages from flooding (Table 5). Dunes with a high, medium and low function value were given a reduction in damages percentage based on a moderate stepwise decline. The doubling of the percentage reduction in damages between low and medium functional values was implemented to reflect protection likely to be provided by a moderate increase in the size of dunes.

A percentage reduction in damages of 80% was given to Shingle with a very high functional value (Table 5). This percentage was based on the expectation that a shingle bank is unlikely to act as a complete barrier for all extreme storm and flooding events and some overtopping or breaching may occur. Percentages for high, medium and low functional values follow a similar decline to sand dunes.

Saltmarsh with a medium functional value was assigned a percentage reduction in damages of 34.5%. This value was based on the average reduction in flood extent reported in Fairchild et al. (2021). This study used numerical hydrodynamic models to assess the flood protection potential of eight estuarine saltmarshes in Wales under storms of varying intensity. As a result, the average value derived reflects a range of locations with varying hydrodynamic settings. The average reduction was based on modelling broad estuary-level effects of storm scenarios (Fairchild et al., 2021). There is the potential that reduction in damages may be influenced further by local or fine-scale factors.

Fairchild et al. (ibid) also reported a standard deviation around the average of 24.1%. This variability around the mean was added to and subtracted from the average value to derive the reduction in damages percentages for saltmarsh with high and low functional values, respectively. A value of 80% was used for saltmarsh with a functional value of very high because as saltmarsh attenuate waves and tidal flows, as opposed to acting as a barrier, total protection even for a very wide saltmarsh is not certain.

Table 5 Reduction in damages assigned to the functional value of dunes, shingle and saltmarsh

Functional Value	% reduction in damages: sand dune	% reduction in damages: shingle	% reduction in damages: saltmarsh
Very High	100%	80%	80%
High	80%	65%	58.6%
Medium	60%	50%	34.5%
Low	30%	25%	10.4%

Once the reduction in damage percentages were assigned to each habitat within a Coastal Unit, they were scaled (multiplied) by the proportion of the coastline length within the Coastal Unit that fronted by each habitat (see Phase 3). This provided a high-level estimate of the proportion of the coastline protected by each habitat, and hence its contribution to reducing flood damages.

Lastly, in order to generate an overall percentage reduction in flood damages provided by all habitats within a Coastal Unit, the scaled percentages were added together. Any summed values that exceeded 100% were capped to 100% and it was assumed they provide a total reduction in flood damages.

2.7. Phase 5: Estimating the economic value of the reduction in flood damages

This section is broadly split into two parts. The first part provides an overview of the ecosystem accounting process and the concept of ecosystem accounting. The second part details the approach taken to implement the ecosystem accounting process, providing detailed methods for the benefits provided by coastal habitats (i.e., saltmarsh, sand dunes, and shingles) in Wales.

2.7.1. Ecosystem accounting process

This section presents the background and concepts of natural capital and ecosystem services, and describes the process that produces ecosystem accounts and the structure of the accounts.

Ecosystem accounting is a process of compiling and linking data on the quantity and quality of ecosystem assets and physical and monetary data on the benefits they provide. The data are presented in a consistent framework, which should, as far as possible, align with the System of Environmental Economic Accounting – Ecosystem Accounting (SEEA-EA) standards for producing ecosystem accounts (UN, 2021). These accounts present evidence to measure and monitor benefits from ecosystems consistently over time to inform policy and planning decisions.

In the same way that the structured recording of other national statistics in conventional, national accounts inform and improve a country's economic and social decisions, ecosystem accounts can inform better management of a country's ecosystem assets. Ecosystem accounts are structured as a set of interrelated component accounts that record the value that is provided by a country's ecosystem assets. The aim of these accounts is to answer the following key questions:

- What ecosystem assets do we have? An **Ecosystem Extent and Condition Account** (together sometimes referred to as an asset register) is an inventory that holds details of the stocks of ecosystem assets that are present within the geographical boundary of the country. The asset register helps track trends in the quantity and quality of ecosystems.
- What benefits do these assets provide? **An Ecosystem Services Flow Account (physical terms)** contains the flow of goods and services which are dependent on the ecosystems that are identified in the extent and condition accounts. This account provides information on the benefits provided by ecosystems, with the flows measured in different physical units (e.g., number of residential properties protected from flooding, number of recreational visits to a green space).
- What is the value of these benefits? An **Ecosystem Services Flow Account (monetary terms)** calculates the annual value of the estimated flow of goods and services that are captured in the Ecosystem Services Flow Accounts (physical terms).

As applied in this report, the SEEA-EA standard for ecosystem accounting can be thought of as a subset of the broader process of natural capital accounting. They generally apply the same concepts and methods. SEEA-EA does so in a more specific way to align with the System of National Accounts (which is the internationally agreed standard set of recommendations on how to compile measures of economic activity, such as GDP).

2.7.2. Implementation of ecosystem accounting

This section outlines the implementation of the ecosystem accounting process. The ecosystem assets assessed in this account include saltmarsh, sand dunes, and shingle which provide flood mitigation benefits to coastal communities in Wales. The flood mitigation benefits provided by these habitats are measured according to the protection provided to:

- Properties – across residential and commercial properties;
- Agricultural land – across agricultural land classes (ALC); and
- Infrastructure – across rail and road infrastructure.

It should be noted that while agricultural land is included in this account as an asset protected by coastal habitats, it is not assessed as an ecosystem asset. Its inclusion is limited to its role as a beneficiary of regulating services provided by coastal ecosystems, specifically with regard to the valuation of avoided flood damage. A comprehensive natural capital account for Wales would consider agricultural land as an ecosystem asset in its own right, incorporating a broader range of ecosystem services.

The benefits are estimated as the difference between a baseline scenario in which the ecosystem assets are present, and therefore providing flood mitigation benefits, to a scenario in which the assets are not present (i.e. highly degraded ecosystems) and therefore do not provide flood mitigation benefits. The baseline scenario considers the current flood risk of properties, agricultural land, and infrastructure in the Coastal Units. The flood risk levels in Wales are defined as:

- High risk means that each year, an area has a chance of flooding of greater than 1 in 30 (3.3%);
- Medium risk means that each year, an area has a chance of flooding of between 1 in 200 (0.5%) and 1 in 30 (3.3%); and
- Low risk means that each year, an area has a chance of flooding of between 1 in 1000 (0.1%) and 1 in 200 (0.5%).

Results in this report are presented at several spatial scales. This includes national level, local authority level, and Coastal Unit level values. The asset register of coastal habitats in Wales (i.e., saltmarsh, sand dune, and shingle) are reported at the local authority level to reflect the distribution of different coastal habitats in Wales. The economic benefits provided by these habitats is summarised at a national level, to provide a comparison of the benefits habitats provide to each asset. The economic benefits for each asset (i.e., properties, agriculture, road, and rail) are also presented in maps at the Coastal Unit level. Coastal Unit level results for property, agriculture and road based on the receptors, agricultural land, or roads within each Coastal Unit boundary. Due to the interconnected nature of rail transport, Coastal Unit level results were more challenging to interpret. In order to calculate Coastal Unit level results for rail, the results for each unique 'rail impact area' (Figure 2.8) were estimated and apportioned equally to each Coastal Unit within the 'rail impact area'.

Residential and non-residential properties

Flooding impacts on residential and non-residential (i.e. commercial) properties can be significant. The physical account includes the number of residential and non-residential properties in each flood risk level (i.e., low, medium, and high flood risk), based on the NRW (2023) National Receptor Dataset (NRD). The number of properties at each flood risk level has then been apportioned according to the number of properties protected by habitats from flooding based on the percentage protection provided by habitats in each Coastal Unit. It is assumed that without the presence of the habitats, the damage to these properties would increase.

The flood mitigation services provided by saltmarsh, sand dunes, and shingle can be measured as the avoided damage costs to properties. This is by estimating the reduction in flood damages attributable to protection provided by these habitats and calculating the corresponding decrease in expected repair, replacement, and displacement costs that would have been incurred without this natural protection.

The Environment Agency (2018) estimated the costs resulting from the winter floods in England following Storms Desmond, Eva and Frank in December 2015, across a range of impact categories including residential and non-residential property damages. Residential property damages consist of direct damages to building fabric, damage to inventory items and clean-up costs. They estimated costs of between £26,000 and £33,000 per residential property (in 2025 prices). Flooding of non-residential properties results in damage to premises, equipment and fittings, and loss of stock, as well as disruptions of business. The costs to businesses range from £110,000 to £160,000 per non-residential property (ibid.).

These damage costs were applied to residential and non-residential properties according to the number of properties flooded annually. The number of properties flooded annually are estimated according to the number of properties at each flood risk level. These costs are then multiplied by the reduction in damages derived in Phase 4 to estimate the avoided damages costs attributable to saltmarsh, sand dune, and shingle.

These costs are associated with a high degree of uncertainty, and there are a number of ways in which these estimates could be improved in future. The key areas of uncertainty include:

- **Avoided damage costs do not reflect attributes of properties in the Coastal Unit**. Damage costs to residential properties do not reflect size and age of properties, or property type (e.g., detached, semi-detached, etc.). Damage costs to non-residential properties do not account for differences across type of businesses (e.g., warehouses, cafes, shops, etc.). Future assessments should license the Multi Coloured Manual (MCM) Handbook to access information on damage costs per property type.
- **Avoided damage cost estimates do not capture key flood characteristics that influence costs**. Current calculations do not account for flood depth, duration, or warning time, which affect the extent of damage and recovery costs. Without these factors, estimates may be misleading or difficult to interpret, making it challenging to communicate flood risk effectively. Future assessments should incorporate detailed flood data, such as return periods, water depth, and inundation duration to refine damage estimates.

Agricultural land

Flooding can affect the profitability of farm businesses, temporarily for a one-off flood, or permanently if there is a persistent increase in flood frequency (Penning-Rowsell et al., 2013). The damage costs due to flooding on farmland depend mainly on the type and productivity of land use, the duration and seasonal timing of flooding and a number of local factors that influence damage costs at the farm scale (ibid.).

The benefits to agricultural land provided by habitats providing flooding protection (i.e., saltmarsh, sand dunes, and shingle) have been estimated according to (1) the avoided loss of existing agricultural production from flooding and (2) avoided loss of converting arable land to grazing land (where that would be less costly than regular flooding losses to arable crops).

The first approach estimated the benefits provided by natural habitats in terms of the avoided loss of existing agricultural production due to flooding. This is based on the area of agricultural land that is protected from flooding according to the flood risk level and the Agricultural Land Classification (ALC) grade of the land protected.

ALC uses a grading system to assess and compare the quality of agricultural land in Wales. A combination of climate, topography and soil characteristics and their unique interaction determines the limitation and grade of the land. These affect the range of crops that can be grown, yield of crop, consistency of yield, and cost of producing the crop. ALC is graded from 1 to 5 with the highest grade being for land with the greatest yield and versatility in the crops that can be grown. This classification influences the value of the land and the cost of flood-related damage.

The flood risk levels were overlaid to estimate the proportion of land likely to be flooded in a given year. For example, in low flood risk zones (with a 0.1% to 0.5% annual probability of flooding), it was assumed that a corresponding proportion of the total land area in that zone would be flooded annually in the absence of habitat protection.

The cost of flooding was then applied to these areas. This was done using damage cost estimates that vary by ALC grade, reflecting differences in typical yields, land use types, and production values. For example, grades 1 and 2 land, which generally supports intensive arable production, was assigned a higher cost per hectare due to the higher economic losses associated with these areas being flooded. The costs of flooding by ALC grade are shown in Table 6.

Table 6 Costs of a single annual flood of one week or more by ALC grade, weighted according to the distribution of land use and England and Wales monthly distribution of flooding and distribution of land use, 2025 prices.

ALC grade	Weighted cost of flooding (£/ha) 2025 prices
1	1,820
2	1,379
3a	827
3b	469
4	248
5	138

Source: Penning-Rowsell et al. (2013).

The result was an estimate of the annual economic benefit of habitat-based flood protection to agricultural land, calculated as the avoided loss of agricultural production. This approach captures how coastal and estuarine habitats reduce direct losses to farm output by mitigating flood exposure across a range of land types and qualities.

However, it should be noted that flooding by saline water usually causes more damage to crops and soils than flooding by freshwater. High salt concentrations cause crop stress, restricted growth and complete failure, especially during germination and establishment. Penalties for saline inundation are likely to be between 10 percent and 20 percent higher than for fluvial flooding, depending on salt tolerance. Coastal flooding also tends to have a longer duration than fluvial flooding. The impact of saline flooding to arable land has not been modelled as these impacts vary according to the time of year of flooding, and in which crops are planted, and the types of crops grown. The overall benefits provided by habitats in protecting agricultural land against coastal flooding is therefore expected to be underestimated. Future research should seek to integrate this variable to more accurately assess the avoided impacts from saline flooding.

The second approach focused on the avoided replacement of higher-value arable land with lower-value grazing land as a result of the flooding protection provided by habitats. This approach assumes that ALC grade 1 and 2 land located in areas with a high risk of flooding, where more than 80 percent of flood protection is attributed to natural habitats, would not be used for arable production in the absence of those habitats.

In such high-risk areas, without the protection provided by habitats, it is likely that intensive arable farming would be economically unviable due to the increased frequency and/or severity of flooding. As a result, the land would likely be converted to extensive grazing, which is more resilient to flooding but generates significantly lower returns.

The value of the protection provided by natural habitats was therefore estimated as the difference in land value between intensive arable land and extensive grassland, based on average per-hectare land values (shown in Table 7). By applying this value difference to the area of grade 1 and 2 land fitting the above criteria (i.e., at high flood risk and with habitats providing more than 80% of the flood protection), the annual benefit of habitat-based flood protection was calculated in terms of preserving higher-value land use and maintaining productive capacity.

Table 7 Indicative estimates of land market prices (£/ha) by type of land use, 2025 prices.

Land type	Land market prices (£/ha) 2025 prices (low estimate)	Land market prices (£/ha) 2025 prices (high estimate)
Intensive arable	19,000	25,000
Extensive arable	18,000	21,000
Intensive grass	18,000	21,000
Extensive grass	10,000	14,000

Source: Penning-Rowsell et al. (2013)

In a ‘perfect’ market, agricultural land prices reflect the income-earning potential of farmland over a reasonable time horizon. That is, the discounted present value of a series of future annual benefits (net of costs) from agricultural production, thus, in theory, the permanent loss of future agricultural output (£/ha) can be expressed in terms of a loss of land value (£/ha).

The avoided costs estimated using these two approaches are summed to provide a total value of flood protection benefits, as they capture distinct types of avoided damages on distinct areas of agricultural land. However, it is important to note that these are not two separate approaches, but rather two calculations within an overarching decision-making framework. In practice, a farmer would evaluate the expected value of maintaining the current land use versus switching to an alternative use, accounting for flood-related losses in both cases, and select the best overall option.

The current methodology assumed that flood protection benefits are fully captured by one of the two approaches, depending on the land's flood risk and the protection level provided. However, it is worth noting that converting from intensive arable to extensive grazing does not imply zero damage under the first approach, but rather reduced damage, as the land will still experience some flooding. Future research could refine this approach by moving beyond the weighted average of land use types and intensities for each ALC grade, instead modelling each land use explicitly. This would enable a more precise calculation of expected losses and guide the selection of the most economically optimal land use for each specific parcel of land.

Road

The flooding of roads can cause significant damage and disruption for travellers, which come with associated costs (Penning-Rowsell et al., 2013).

For each Coastal Unit, the length of motorway, A-road, B-road and minor road at risk of flooding (i.e., with a high, medium, and low flood risk) were identified from the OS Open Roads data layer (Ordnance Survey, 2024a). Where the same road passed through multiple flood risk levels, the highest flood risk classification was used, based on the assumption that if one part of a road is frequently flooded, traffic on the rest of the road is also likely to be affected.

The 'delayed-hour method' was used to estimate the economic costs of road traffic disruptions due to flooding. Based on this approach, it was assumed that flooding would lead to vehicles being diverted onto nearby roads, therefore increasing their travel distance and time while maintaining the same speed. Delay times were calculated as a function of diversion length and speed (determined by speed limits).

In line with assumptions made by Fairchild et al. (2021), it was assumed that diversions extend the journey by a distance equal to the length of road made impassable by the flood water. This means that road users would need to double the travel distance due to flooding – with half of this distance being the distance that would have been travelled anyway and the other half of the distance being additional and therefore a consequence of the flooding itself. If the flooded road segment was less than 1 km in length, a minimum diversion length of 1 km was applied. For flooded segments on major roads (e.g., A roads) that were shorter than 2 km, the Standards for Highways (2022) minimum reported distance between junctions on motorways and A roads, 2 km, was used (DfT, 2025). Delay times were calculated as a function of diversion length and speed, using average speeds observed for each vehicle type and road type (DfT, 2023b) to estimate travel time, calculated as distance divided by speed.

Based on the assumptions made by Fairchild et al. (2021), it has been assumed that disruptions occur for a period of 12 hours. This 12-hour disruption period reflects the generally higher resilience of road infrastructure, which is often elevated above surrounding land and has drainage systems that facilitate relatively rapid recovery following flood events. In contrast, flooding of agricultural land is assumed to result in impacts lasting a week or more, as agricultural land typically lacks such drainage infrastructure and is often situated at lower elevations, resulting in slower water removal.

The number of vehicles affected by these diversions was based on road traffic data published by DfT (2023a) for major and minor roads across Wales. Where available, traffic counts for specific roads identified as being at risk of coastal flooding (e.g., M4, A40, B4236) were used directly and disaggregated by vehicle type (cars, light goods vehicles, other goods vehicles, and public service vehicles). If a direct match to the DfT dataset was not possible, average daily traffic volumes for the corresponding road type and local authority were used as a proxy.

The benefits of flood risk management include reducing the time lost due to diversions that occur when roads are inundated (Penning-Rowsell et al., 2013). This analysis estimated first order impacts of such disruption, namely increased journey time. Second order impacts not estimated include increased traffic on diverted routes, causing further delays. The value of a change in travel time is the change in welfare expressed in monetary terms. The values of travel time savings represent the opportunity costs of time spent by travellers during their journeys. The travel time costs used to estimate the avoided delay costs due to flooding are shown in Table 8.

Table 8 Total resource costs of travel as a function of speed (£/hour/vehicle), 2025 prices.

Vehicle type	Values of travel time per vehicle (£/hour/vehicle)
Car	18
Other vehicles (e.g., LGVs, OGVs, etc.)	24

Source: DfT (2024)

Rail

Delays and cancellations to rail services due to flooding cause disruption for passengers and freight carriers, resulting in associated costs. Compensation payments made to train operating companies (TOCs) and freight operating companies (FOCs) by Network Rail to recompense for delayed or cancelled services are used to estimate the costs associated with flooding. This approach uses the number of services that would be impacted by flooding without the protection of habitats (i.e., the avoided service disruptions).

Rail segments (Ordnance Survey, 2024b) were grouped into 20 unique local, regional, national and principal lines as per Network Rail (2024). An estimated 1,340 services run each day in Wales (Network Rail, 2025), and these services were apportioned to each line according to the average number of services per day per line type (Trainline, 2025; Table 9). The frequency of freight services was provided directly by Network Rail.

Table 9 Number of passenger services per day on principal, regional and local rail lines (Trainline, 2025)

Rail line type	Number of passengers (low estimate)	Number of passengers (central estimate)	Number of passengers (high estimate)
Principal	116	166	215
Regional	12	20	27
Local	7	10	13

The number of stations (Pope, 2017) on each line was calculated as well as the portion of stations on each line which would be affected by high risk flooding. To estimate the proportion of stations at high risk, segments of rail lines that intersected high risk flood areas, as defined by NRW (2023) in the NRD, were used. Any station within the high flood risk areas or stations stranded between two high risk areas were marked within a high risk rail impact area (Figure 2.8).

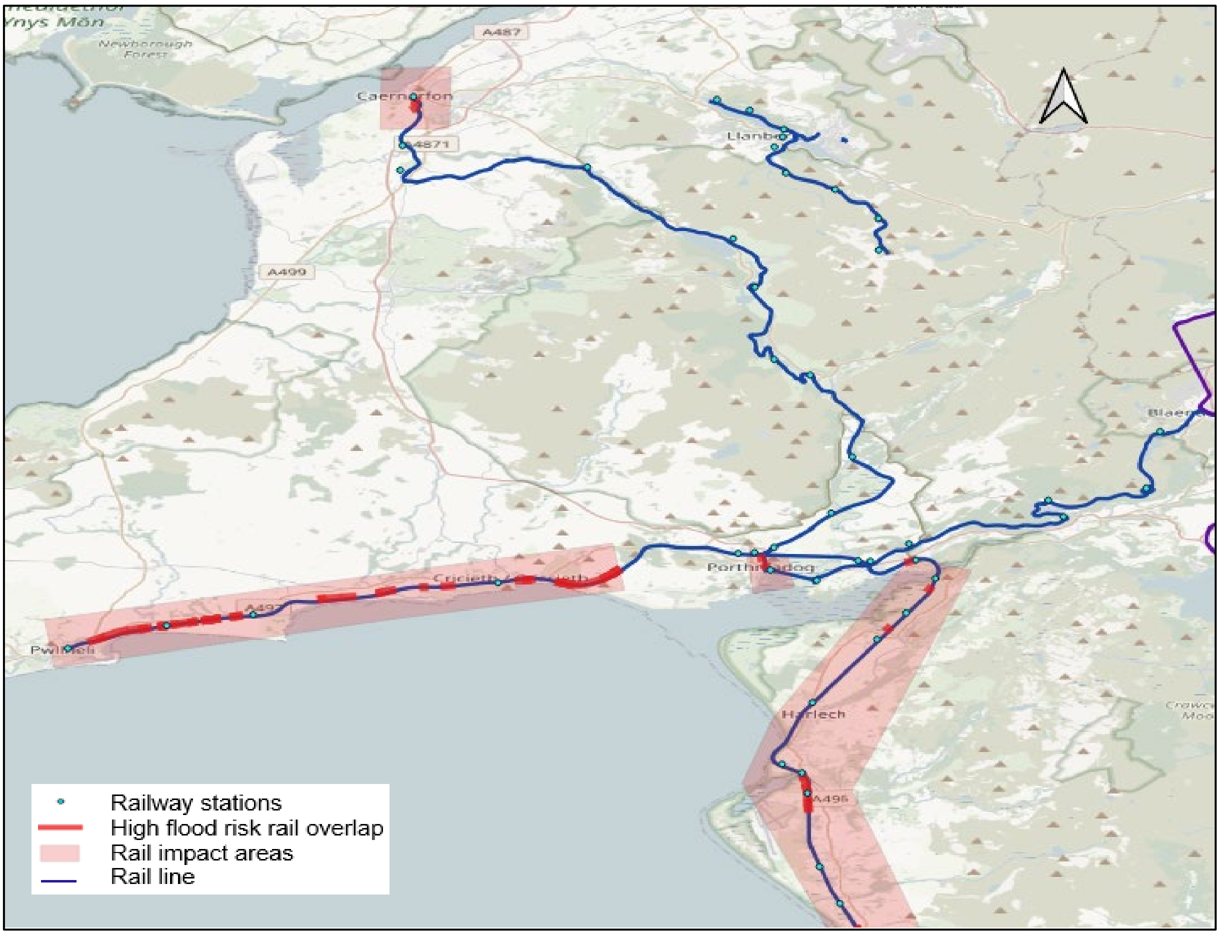


Figure 2.8 Example of rail impact area grouping used to estimate the number of services affected by flooding

Whilst the baseline flood risk data also contains medium and low flood risk areas, there were no railway stations in low or medium risk areas that were not already attributed a high risk.

The percentage of high-risk stations per line was calculated, and this proportion was used to estimate the number of daily services on each line affected by flooding. Importantly, the 'rail impact areas' factor in connectivity between areas that are not flooded. In Figure 2.8, whilst there is flooding on the northern tip of the rail line, the remainder of that spur of the line is not at risk and is connected to the eastern line going inland. Due to this, it is assumed that portion of the line continues to operate services.

To estimate the number of services impacted by flooding on an annual basis, the number of services operating annually across high-flood risk areas were multiplied by the annual risk of flooding (ranging from 3.3% to 16.5% in high flood-risk zones).

To account for the role of natural habitats in flood mitigation, the number of services impacted by flooding annually was further adjusted based on the proportion of each line protected by habitats. Rail lines run through a number of different coastal units, in which coastal habitats provide varying levels of protection. Habitat protection was attributed based on the lowest percentage protection value observed across the Coastal Units intersecting each high-risk segment. This approach ensured that the weakest point of protection on any given rail line segment was used, as flooding will occur where protection is weakest and will nonetheless affect other parts of the rail segment. It was assumed these services would have otherwise been cancelled. This was calculated for both passenger and freight services.

The cost of cancellation per service is shown in Table 10, and is based on indicative compensation payments per cancelled service (Penning-Rowsell et al., 2013), inflated to 2025 prices. It was assumed that all impacted services are cancelled for 24 hours due to flooding.

Low, medium, and high compensations values were provided for passenger service cancellations (per service) to account for the wide variation between TOCs and the lines impacted. A single indicative value for cancellation of freight trains was provided as, unlike passenger services, there is little variation in the unit compensation values. These values were multiplied by the estimated number of avoided service cancelations to provide an approximation of the avoided losses due to habitat protection from flooding.

Table 10 Indicative cancellation compensation values (£ per service cancelled) for cancelled services, 2025 prices

Service Type	Cancellation compensation value (Low)	Cancellation compensation value (Medium)	Cancellation compensation value (High)
Passenger Services	943	2,849	3,630
Freight Services	2,662	2,662	2,662

Source: Penning-Rowsell et al. (2013)

Although this approach attempts to provide an estimate for the avoided rail disruption costs from flooding, there are high uncertainties, including:

- **The number of services affected by flooding**. The proportion of services cancelled on a given line is uncertain as it is estimated according to the proportion of stations impacted by flooding, however, the number of services impacted may not be directly proportionate to the number of stations impacted.
- **The approach only accounts for service cancellation** and does not include any infrastructure or rolling stock damage, nor the potential costs related to accidents, cleanup, other operational impacts arising from flooding, or service delays.

3. Results

3.1. Habitat contribution to reduction in flood damages

In total, there were 380 Coastal Units around the Welsh coastline and 285 of them were fronted by sand dunes, shingle, and/or saltmarsh. Saltmarsh was present in 62% of these Coastal Units, with dunes and shingle present in 34% and 55%, respectively.

A summary of the number of coastal units with dunes, shingle or saltmarsh within each functional value category is provided in Table 11.

Table 11 Number of dune, shingle or saltmarsh within each functional value category across all Coastal Units

Habitat	Very high	High	Medium	Low	Total
Dune	25	29	32	10	96
Shingle	9	41	41	65	156
Saltmarsh	26	39	72	40	177

The reduction in damages scores for Coastal Units around Wales are shown in Figure 3.1. A total of 31 Coastal Units had habitats which were deemed to provide more than a 90% reduction in flood damages, and 23 of these had a reduction in damages score of 100%. Examples of the areas where Coastal Units have a high reduction in flood damages score include:

- Merthyr Mawr;
- Kenfig;
- Whiteford/ Llanmadoc;
- Pembrey and Loughor Estuary;
- The coastline between Pendine and Laugharne;
- Tenby;
- Tal-y-bont;
- Tan Y Bwlch;
- The coastline between Tywyn to Aberdovey;
- Morfa Harlech, Morfa Bychan;
- Dwyfor Estuary;
- Dinas Dinlle (Caernarfon Airport);
- Newborough Warren/Forest; and
- Anglesey Airport.

These areas had large extents of sand dune which were typically more than 5 m above HAT and more than 100 m in width (very high functional value). The majority of these sites also had large extents of saltmarsh with a high or very high functional value (e.g. Pembrey, Laugharne, Whiteford/ Llanmadoc, Morfa Harlech, Caernarfon Airport) and/or shingle (e.g. Merthyr Mawr, Tal-y-bont, Tan Y Bwlch, coastline between Tywyn to Aberdovey, Dinas

Dinlle/ Caernarfon Airport). As such, the presence of multiple habitats at a site is more likely to provide a high damage reduction score for that site.

Further, dunes were present in all Coastal Units which had reduction in damages score of more than 85%. These dunes typically had very high or high functional value scores and fronted a large proportion of the coastline.

There were 100 Coastal Units which had a reduction in flood damages score of less than 25%, and 40 of these had a reduction in flood damages score of less than 10%. These are areas where habitats are assumed to not be contributing to reducing flood damage. Examples of areas where the Coastal Units had a low reduction in damages score include:

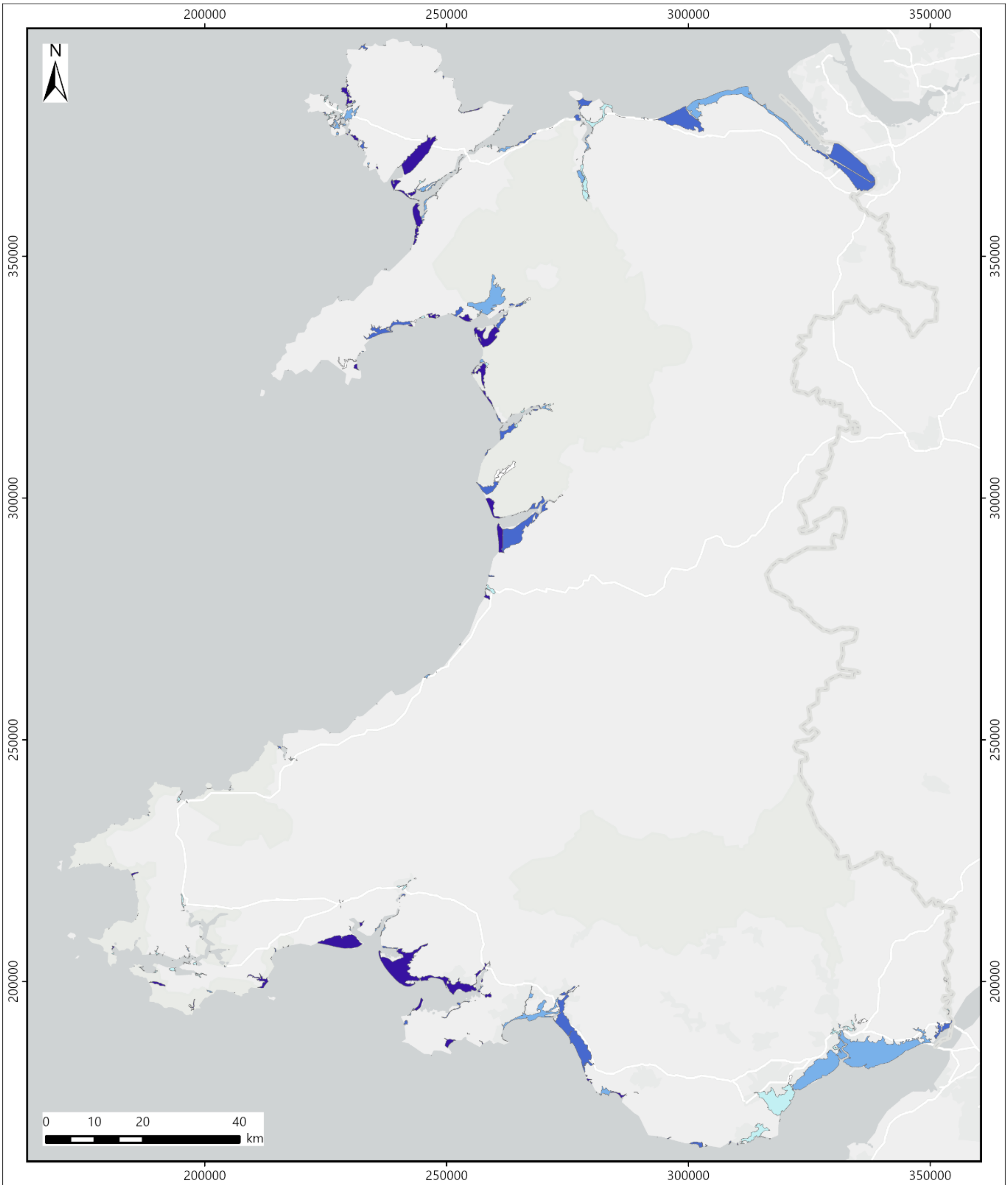
- Cardiff;
- Barry;
- Pembroke Dock;
- Milford Haven; and
- Aberystwyth.

These areas typically had no to small extents of habitats within them.

Other notable Coastal Units where habitats may provide a moderate reduction in flood damages but are less extensive or have a lower functional value included: Swansea Bay, Porthmadog, Newport, and along the coastline from Rhyl to the River Dee.

Examples of Coastal Units with high and low reduction in damages scores are shown in Figure 3.2.

Man-made defences were present in 105 of the coastal units. The majority of the defences were sea walls or embankments.



Date	By	QA
Jun 25	ERP	HKG

Coordinate System
British National Grid

Projection
Transverse Mercator

Project No. 5540
Fig_Final_Results_National_A4

Reduction in damage score (%)

- 0
- 1 to 25
- 25 to 50
- 50 to 75
- 75 to 100

Figure 3.1 Coastal Unit reduction in damages scores across Wales symbolised by the CU associated Accommodation Space

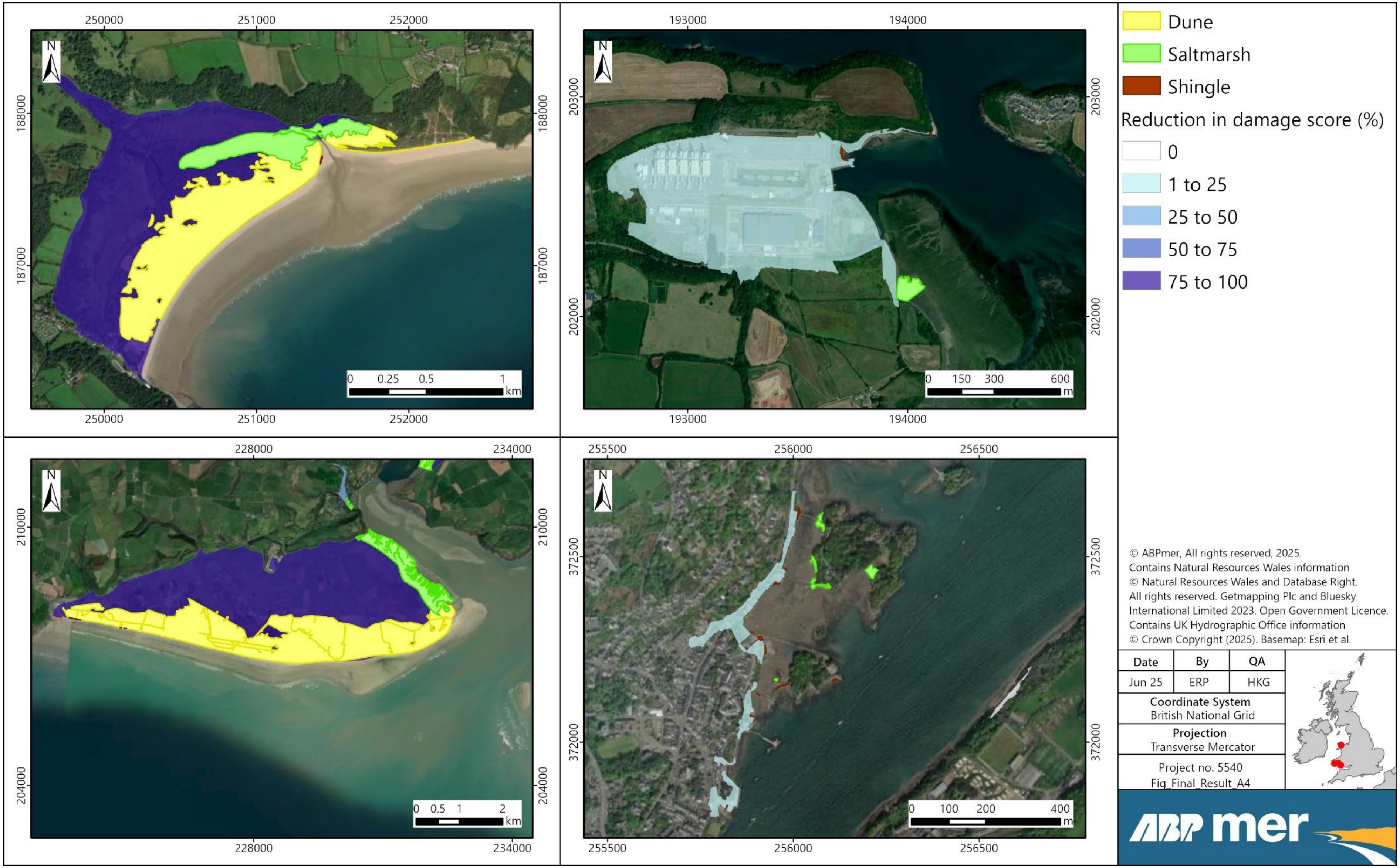


Figure 3.2 Examples of Coastal Units which had high and low reduction in damages scores symbolised by their associated Accommodation Space

3.2. Asset register

The asset register is a registry of all natural capital assets within the boundary of the account. It forms the foundation of the account and records the extent and condition of the assets. In this account, the extent of the assets has been quantified, but it has not been possible to quantify the condition of these assets. The extent of the habitats providing protection against flooding in Wales is reported in Table 12.

Table 12 Overview of asset register by local authority (LA)

Local Authority	Saltmarsh (ha)	Sand dune (ha)	Shingle (ha)	Total habitat area (ha)
Swansea	1,994	1,726	9	3,729
Gwynedd	848	662	98	1,608
Flintshire	883	155	8	1,046
Isle of Anglesey	277	587	30	894
Carmarthenshire	243	600	4	847
Ceredigion	424	152	30	606
Newport	382	-	1	383
Neath Port Talbot	138	174	7	319
Conwy	113	44	54	211
Powys	158	-	0	158
Bridgend	9	116	10	135
Denbighshire	51	72	5	128
Pembrokeshire	15	37	16	68
Monmouthshire	60	-	-	60
Vale of Glamorgan	15	2	28	45
Cardiff	0	-	-	-
Total	**5,557**	**4,254**	**294**	**10,105**

3.3. Ecosystem services flow account

The estimated annual physical and monetary values for the coastal habitats in Wales (i.e., saltmarsh, sand dunes, and shingle) account is summarised in Table 13. The account includes the total count of assets protected by coastal habitats. However, this total does not account for the annual risk of flooding to those assets. The physical account values (low, central, and high estimates) reported in Table 13 reflect the count of assets at risk of flooding on an annual basis, given the range in the risk of flooding each year at each flood risk level (see Section 2.7.2).

The number of properties at high, medium, and low flood risk protected by coastal habitats in Wales is estimated at approximately 20,840 residential properties and 10,714 non-residential properties (see total asset count protected - Table 13). However, this should be interpreted in the context of the actual flood risk level. For example, areas within a Coastal Unit at medium baseline flood risk have 0.5-3.3% change of flooding annually, with a central annual risk of 1.9%.

Based on the probability of a flood event each year and the level of protection provided by habitats, between 40 to 204 residential properties are protected from flooding annually, avoiding damage costs of between £1m and £7m per year. In terms of the protection of non-residential buildings, where a similar number of buildings are protected against flooding each year, the avoided damages amount to between an estimated £4m and £27m in 2025. The avoided damages to residential and non-residential buildings account for 48% of the flood risk benefits provided by coastal habitats in Wales (as estimated within this study).

There are an estimated 16,000 ha of agricultural land at risk of flooding that are protected by coastal habitats. For agriculture, the benefits are twofold. Firstly, habitats could potentially prevent the loss of 380 ha of production from agricultural land annually, with a central estimated saving of £180,000. Secondly, they protect an estimated 58 ha of high-quality arable land from reverting to lower-value grazing land, contributing an additional £610,000 in avoided losses. These values, although smaller than for properties, are important for supporting rural economies and food production over the long term. The relatively small avoided damages to agricultural land can in part be explained by the low productivity of the land that is protected from flooding: 73% of the land at risk of flooding has an ALC of 3b or below. In addition, 70% of the land is at low risk of flooding, meaning the benefits of flood protection are limited for most of the land.

In this assessment, an estimated 47,165 rail services run each year in areas protected by coastal habitats in Wales, helping to avoid 4,670 cancellations to passenger and freight rail services are avoided annually. The avoidance of rail service cancellations across passenger and freight alone provides an estimated £13 million in annual savings. Moreover, the estimated benefits from avoided disruptions to road are 256,000 avoided vehicle hours and corresponding savings of £4.9m a year.

It is important to note that estimates for road and rail are not directly comparable as they employ different valuation methods. The road approach applies the ‘value of time’, which does not account for resource costs such as fuel, while rail estimates employ a compensation value approach. The compensation values consider the costs of the ticket itself as well as level of inconvenience caused. Moreover, road impacts are estimated over a 12-hour period per flood event and rail over a 24-hour period, as flooding on rail infrastructure causes more extensive disruption. There are also fewer options to divert rail routes when compared with road networks, reflecting the higher avoided costs to rail.

Whilst the results estimate expected damage if habitats were not present, these damages may in reality be avoided by new defences such as embankments, thereby reducing the cost of flooding if the cost of such defences is less than the losses in their absence.

A summary of estimated benefit values for the coastal habitats in Wales is provided in Table 13. The total central estimate of benefits provided by coastal habitats estimated in this study amount to £36 million in 2025, largely driven by the avoided damages to properties (48%) and by to the avoided disruptions to rail services (37%). Overall, a conservative approach has been taken to estimating the economic benefits. However, if cheaper responses exist (e.g., building defences) than suffering damages, this may balance out the conservative approach. All of these outputs should be viewed in the context of all of the limitations and assumptions that have been made within the analysis (see Section 4.1).

The range in estimated benefits highlights the high level of uncertainty, particularly in relation to the avoided disruptions to rail services and non-residential properties. The high estimate for these benefits (approximately £28 and £27 million respectively) is more than ten times greater than the low estimate for these benefits (approximately £1.5 and £3.5 million) in 2025. Refining the benefits associated with avoided rail disruptions would greatly reduce the uncertainties in this account.

It is also important to note other benefits are known to be provided by these coastal habitats, such as carbon sequestration, recreation, and biodiversity, which have not been measured in this account. These co-benefits should therefore also be considered in relation to coastal habitat management.

Table 13 Summary of physical (unit/yr) and monetary (£k/yr) estimated values for the coastal habitats in Wales account

Asset type	Asset description	Unit	Total asset count protected (unit/yr)	Physical low estimate (unit/yr)	Physical central estimate (unit/yr)	Physical high estimate (unit/yr)	Valuation metric	Monetary low estimate (£k/yr)	Monetary central estimate (£k/yr)	Monetary high estimate (£k/yr)
Properties	Residential buildings protected from flooding annually	no. properties	20,840	40	122	204	Avoided damage costs to residential properties from flooding	£1,050	£3,670	£6,880
Properties	Non-residential buildings protected from flooding annually	no. properties	10,714	31	95	158	Avoided damage costs to non-residential properties from flooding	£3,490	£13,480	£27,120
Agricultural land	Avoided loss of agricultural production	ha	16,081	124	381	637	Avoided cost from lost agricultural production	£60	£180	£290
Agricultural land	Avoided loss of arable land to grazing land	ha	16,081	58	58	58	Avoided costs from loss of arable land to grazing land	£570	£610	£650

Asset type	Asset description	Unit	Total asset count protected (unit/yr)	Physical low estimate (unit/yr)	Physical central estimate (unit/yr)	Physical high estimate (unit/yr)	Valuation metric	Monetary low estimate (£k/yr)	Monetary central estimate (£k/yr)	Monetary high estimate (£k/yr)
	Number of vehicle hours of flooding disruption avoided	no. vehicle hours	25,772,119	83,667	255,965	428,253	Avoided costs from road disruptions	£1,590	£4,860	£8,130
Rail	Avoided freight services delayed	services cancelled	47,165	47	157	288	Avoided costs of services delayed	£1,420	£12,860	£27,200
Rail	Avoided passenger services cancelled	services cancelled	47,165	1,510	4,513	7,494	Avoided costs of services cancelled	£120	£420	£770
							Total	**£8,300**	**£36,080**	**£71,040**

Note: Monetary values have been rounded to the nearest £10.

3.3.1 Ecosystem services per coastal unit

Whilst the results presented in Sections 3.1 and 3.2 are at the national scale, further work was carried out to report Coastal Unit level results to align with the habitat mapping and scoring. This highlights areas where habitats may be providing an economically important benefit by reducing flood damage costs across Wales.

The total central estimates of flood protection benefit provided by coastal habitats (in terms of avoided losses) across all assets are provided for each Coastal Unit, as shown in Figure 3.3. Figure 3.4 shows the Coastal Units that provide flood protection benefits to rail services in Wales. The benefit provided to rail services across the Coastal Units have been categorised according to the benefits in each ‘rail impact area’, within which there are a number of Coastal Units (see Section 2.7.2). Figure 3.5 shows the Coastal Units that deliver ‘Very Low’ to ‘Very High’ avoided costs from road disruption due to flooding which correspond to the volume of traffic in each Coastal Unit, the associated flood risk levels, and the level of habitat protection provided in the Coastal Unit. Figure 3.6 shows the level of estimated avoided cost to properties, with significant costs shown to be distributed across the Welsh coastline, reflective of the number of properties and level of protection in each Coastal Unit. Figure 3.7 shows level of avoided cost to agricultural land based on how productive the land in a given Coastal Unit is as well as the level of flood protection from habitats.

Overall, large Coastal Units (and hence larger expected extents of floodable area) tended to have a larger number of properties, agricultural land, road and rail services within them. Therefore, the estimated avoided costs associated with the presence of coastal habitats were generally higher in these Coastal Units compared to smaller Coastal Units (Figure 3.3). The areas where habitats have the greatest potential to deliver economically substantial flood risk benefits (exceeding a total of £1 million per annum across all asset types) include:

- Port Talbot;
- Neath;
- Swansea
- The coast between Newport and Caldicot;
- The coast between Pendine to Laugharne;
- Pembrey, Burry Port and Llanelli; and
- The coast from Rhyl to the River Dee.

Among the areas which had high avoided damage costs, the Coastal Units in Carmarthen Bay had high reduction in damages scores as a result of the habitats present (Section 3.1, Figure 3.1). The extensive and high functional value habitats fronting Pembrey, Burry Port and Llanelli were estimated to provide very high avoided damages costs to all of the asset types. Similarly, the extensive and high functional value habitats fronting the coast between Pendine and Laugharne were estimated to provide a substantial avoided damage cost for commercial property and agricultural land.

Not all of the areas highlighted above scored highly in terms of the reduction in flood damages provided by the habitats (Section 3.1, Figure 3.1). Port Talbot, Swansea, the coast between Newport and Caldicot, and the stretch of coastline from Rhyl to the River Dee had reduction in damages scores of 65%, 49%, 46% and 48% respectively. Nonetheless, these areas have moderate extents of high functional value habitats that front extensive areas of residential, commercial and industrial land. Port Talbot, Swansea and the coastline from Rhyl to the River Dee also have substantial stretches of rail infrastructure.

The habitats within the Coastal Unit at Neath, which had flood risk benefit exceeding £1 million across all assets, were estimated to provide high avoided disruption costs to rail services. This was because Coastal Units containing key rail infrastructure within high flood risk zones demonstrated significant cost savings where natural habitats are present along the coastline (Figure 3.4). Neath is located on the main rail line through Wales with connections to Swansea, Cardiff, and Port Talbot, as well as direct services to London. Northern Coastal Units that have a regional rail line running through them also have high avoided disruption costs.

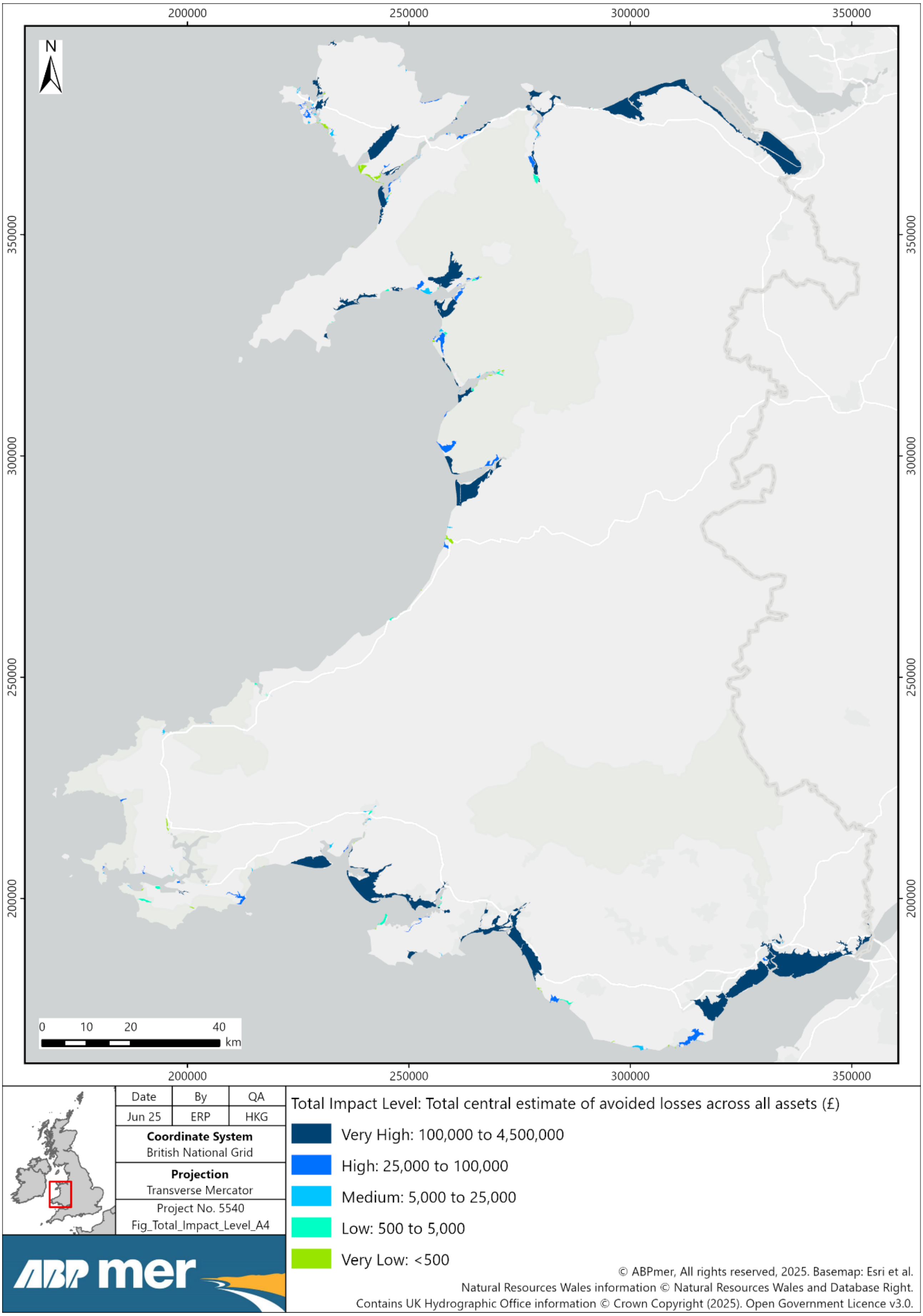


Figure 3.3 The total estimated avoided losses across all assets by Coastal Unit, symbolised by the associated Accommodation Space.

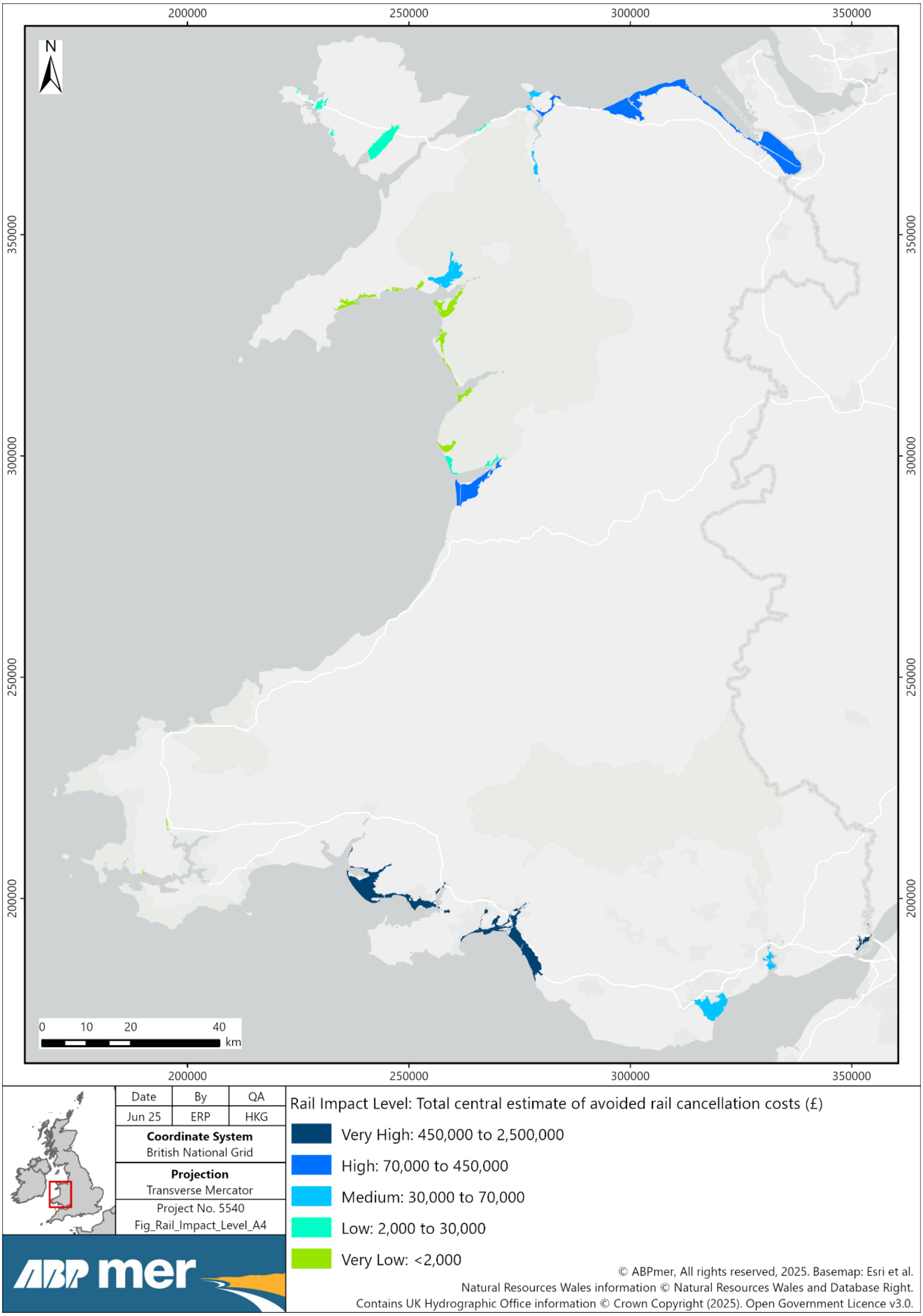


Figure 3.4 The estimated habitat flood protection benefits on rail disruption costs by Coastal Unit, symbolised by the associated Accommodation Space. Note that Coastal Units with zero effect are not shown.

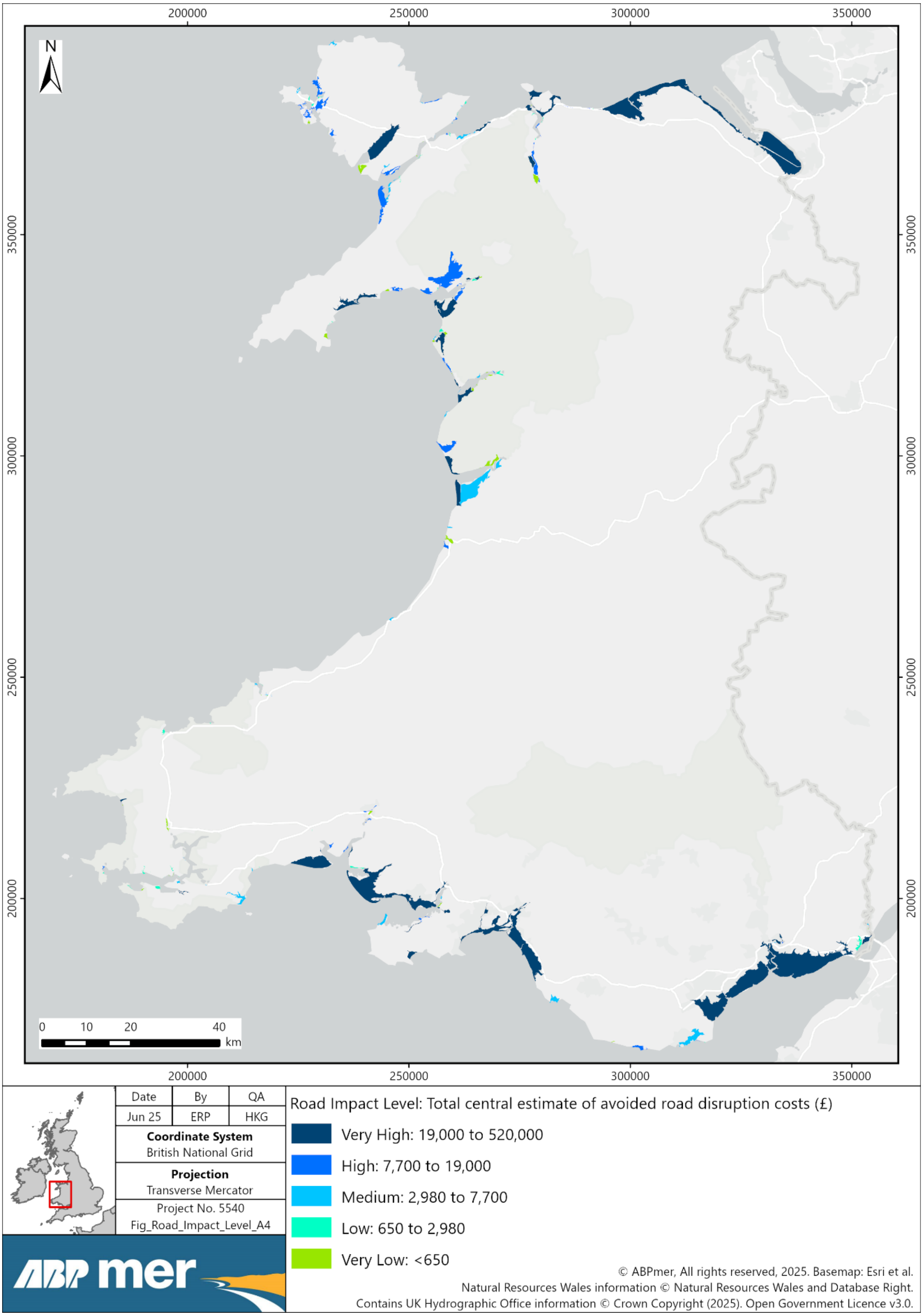


Figure 3.5 The estimated habitat flood protection benefits on road disruption costs by Coastal Unit, symbolised by the associated Accommodation Space. Note that Coastal Units with zero effect are not shown.

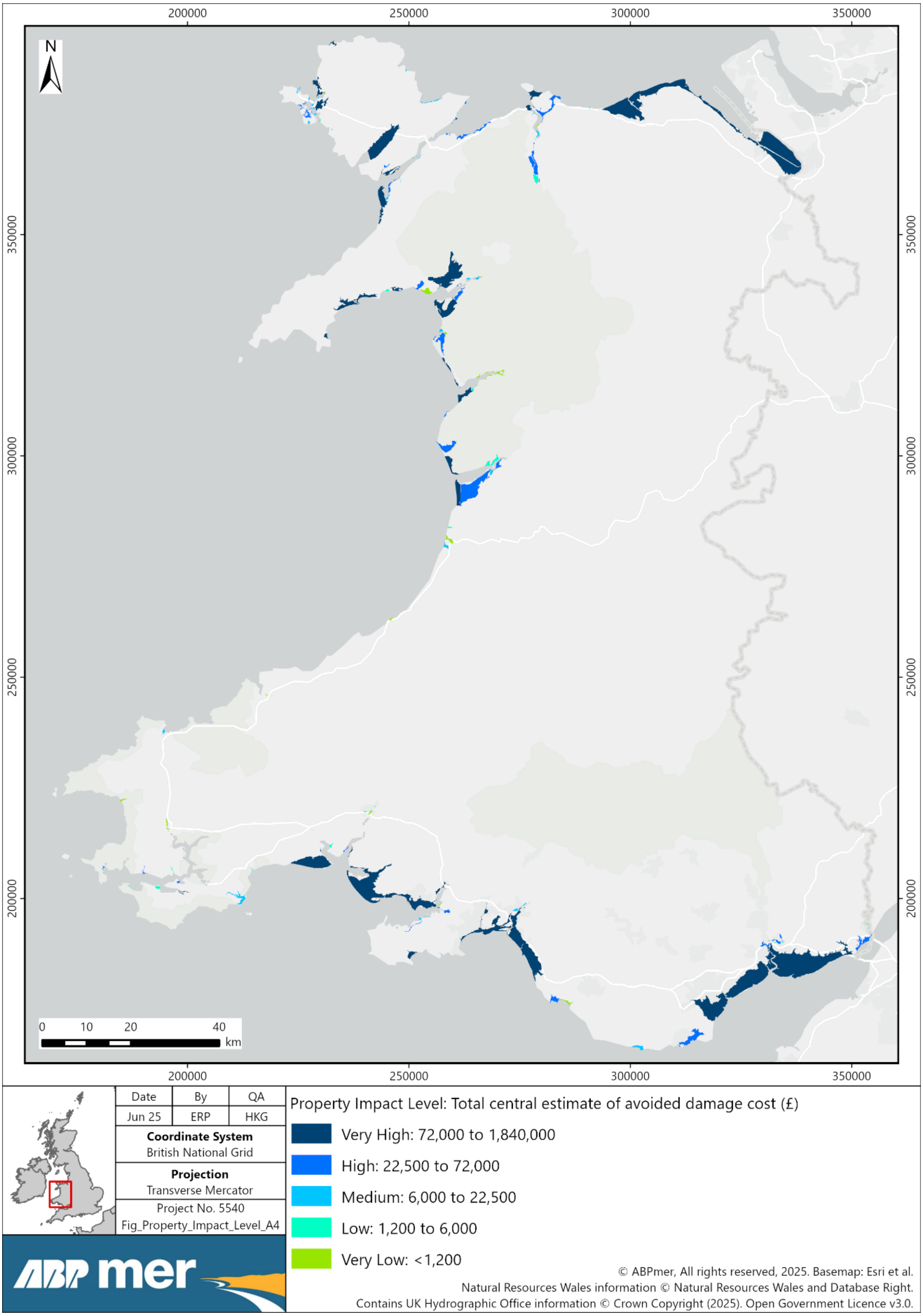


Figure 3.6 The estimated habitat flood protection benefits on residential and commercial property damage by Coastal Unit, symbolised by the associated Accommodation Space. Note that Coastal Units with zero effect are not shown.

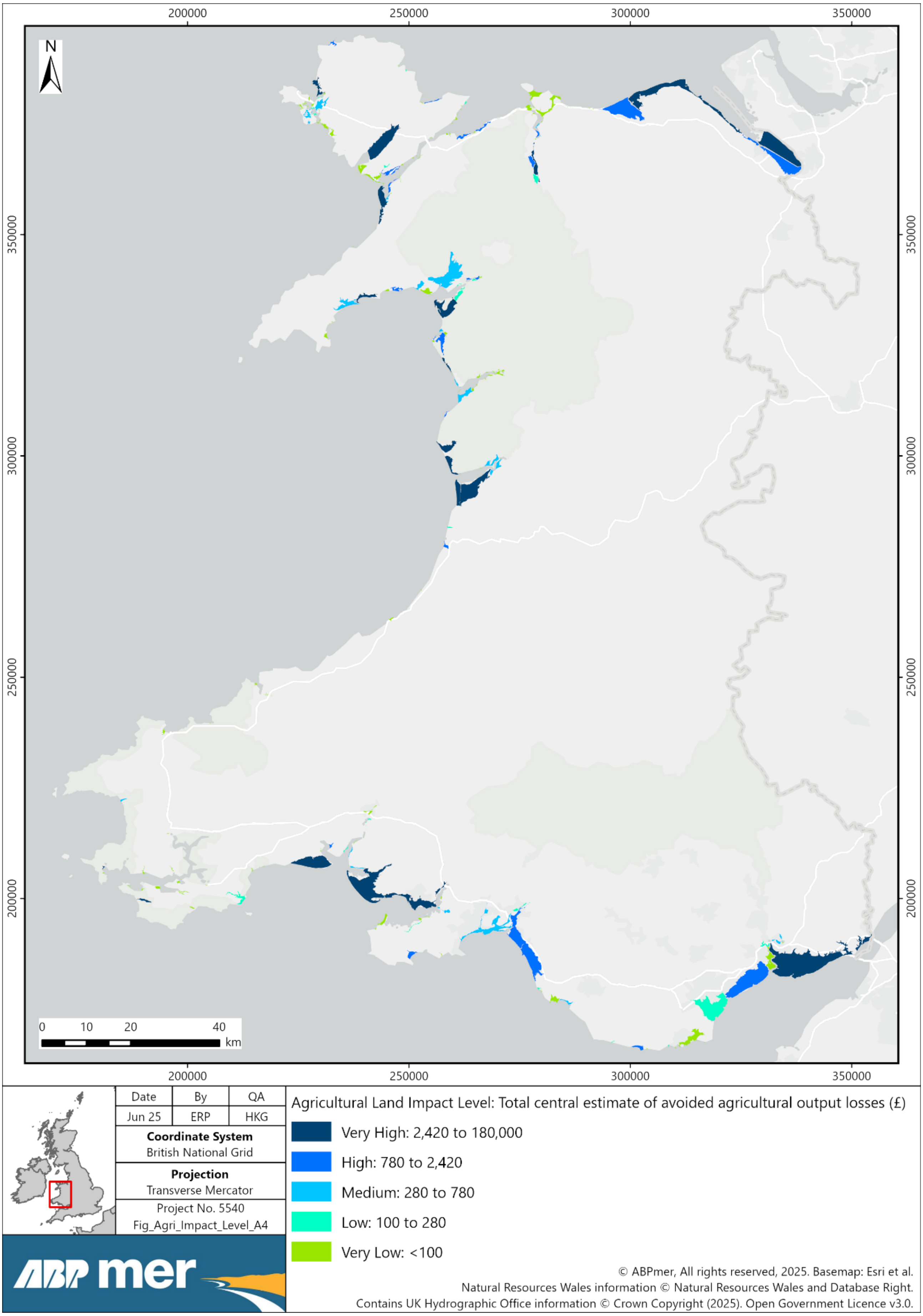


Figure 3.7 The estimated habitat flood protection benefits on agricultural production by Coastal Unit, symbolised by the associated Accommodation Space. Note that Coastal Units with zero effect are not shown.

4. Next Steps and Recommendations

4.1. Assumptions and limitations

This section details the assumptions and limitations of the assessment. These ultimately reflect the national scale level of the project and the data layers used in the assessment presented the best opportunity for data analysis at a national scale. Overall, however, it is acknowledged that in reality, local influences will be important in determining the site-specific flood risk benefit of habitats; for example, fine scale positional relationships between habitats and assets would be required to determine more granular cost-benefits.

There are a number of assumptions and limitations to the approach that was taken to determine functional and flood risk values, namely:

- **Determining functional value and reduction in damages scores.** One of the main limitations of this study was the creation of functional values and defining percentage reduction in damages. Both were primarily based on expert judgement, from evidence that is currently available on flood risk reduction potential of coastal habitats. The values used provide a broad estimate of the potential functional value across the habitats in Wales and across different settings (e.g. at the open coast or estuary level) and allows for an identification of key areas where habitats likely provide a potentially substantial flood risk benefit relative to other locations around Wales.
- **Use of maximum height and derived width of habitats.** This study used maximum height (for dunes and shingle) and an average derived width (for sand dunes and saltmarsh) to characterise the habitats to determine their functional value. Maximum height was used to more accurately represent the height of the crest of the natural frontage, however, dips or drops in the height of the crest may be present in reality. Similarly, one value was also used to define the width of a habitat within each Coastal Unit, whereas in reality habitats are not uniform in shape.
- **Reduction of wave energy across habitats.** Given the high-level nature of this study, it was assumed that the reduction in wave energy would be linear across the width of a saltmarsh and sand dunes (and hence the wider the habitat the more protection it provides). However, as highlighted by some studies (Möller and Spencer, 2002), reduction in wave energy can be non-linear and vary across the surface of a habitat, with the highest reductions in energy occurring within the first few tens of metres.
- **Obtaining a total reduction in damages score per Coastal Unit.** The total percentage reduction in damages was based on summing up the score for each habitat within the Coastal Unit. Whilst this provides a high-level overview of the reduction in flood damage of all habitats together, it is unlikely to capture how these habitats interact with one another, particularly where habitats may front each other.
- **Determining relative importance of habitats to one another.** The percentage reduction in flood damages was determined individually for each habitat type. This allowed a weighting to be applied to account for the difference in importance of the habitats at mitigating flood risk. Dunes and shingle banks are expected to provide a higher level of protection compared to saltmarsh as they provide a physical barrier to tidal flooding and waves. However, the importance of these habitats relative to one another is not quantified on a national scale and was only based on expert judgement for this study.

- **Influence of man-made defences on flood mitigation.** The presence of man-made coastal flood and erosion defences have been captured within the baseline flood risk data (FRAW) used in this study. The impact of man-made defences on mitigating flood risk has therefore been captured to some extent within the ecosystem accounting process as it is based on the assets within each of the flood risk zones. However, defences were not explicitly factored into the reduction in damages score. The interactions between man-made defences and habitats in mitigating coastal flooding is likely site-specific and would require detailed investigations to determine their individual and combined benefits.
- **Other habitat characteristics can influence flood benefit.** The primary characteristics that were used to estimate flood risk reduction in this study were based solely on widths, heights and proportion of the coast fronted. However, other factors will influence the levels of reduction. For example, for saltmarsh, these include vegetation type, height and density, channel dimensions and wider coastal landscape settings (estuarine or coastal).
- **Other oceanographic factors influencing flood risk benefit.** The benefit of habitats for reducing flood risk would be influenced by a range of other oceanographic factors not considered in this study, including but not limited to:
    - Wave height;
    - Wave energy;
    - Tidal range;
    - Storm severity;
    - Tidal flows; and
    - Depth of flood water.

There are a number of refinements that could also be made to improve the accuracy of the ecosystem services physical and monetary account in future, including:

- **Uncertainty in the future risk of flooding**. The avoided damages and costs from flooding have been estimated based on a low, central, and high probability of flooding but it is unknown how frequently a flooding event will occur, and whether the frequency will increase with climate change. Any future increase in flooding frequency would increase the flood mitigation benefit value of coastal habitats in Wales.
- **Uncertainty in the avoided damage costs to properties from flooding**. The value of coastal habitats in protecting properties against flooding has been estimated using the damage costs reported by the Environment Agency (2018). These damage costs are for residential and non-residential properties broadly. The accuracy of these costs could be improved according to (1) the type of property flooded (i.e., detached residential property, warehouses, shops, etc.) and (2) the intensity of a flood event (i.e., flood depth, warning time, etc.).
- **Integrating the impacts of saline flooding to agricultural land**. Saline water usually causes more damage to crops and soils than flooding by fresh water. Coastal flooding also tends to have a longer duration than fluvial flooding. Future research should seek to model the impacts of coastal flooding according to the distribution of seasonal flooding alongside crop germination/planting patterns and crop tolerance to saline water. This would increase the accuracy of the benefits provided by coastal habitats in protecting agricultural land.
- **Modelling the expected value of different agricultural land uses under varying levels of flood risk both with and without habitat-based protection**. This would allow for the selection of the economically optimal land use for each parcel, based on a comparison of expected returns accounting for flood damages. The two

valuation approaches used to estimate the avoided costs to agricultural land are currently applied to distinct areas and summed to estimate total benefits. However, these are components of a single overarching decision-making framework, whereby a land manager would evaluate the expected economic returns of maintaining current land use versus switching to an alternative, incorporating flood-related losses in both cases. Additionally, the conversion of land from intensive arable to extensive grazing does not eliminate flood damage altogether, it merely reduces it, suggesting that some refinement of the costs from lost agricultural production would be needed to capture residual losses more accurately. This would likely require modelling land use and flood vulnerability at a more granular level, rather than using weighted averages by ALC grade.

4.2. Recommendations

This section provides recommendations on how this national-scale project could be refined:

- Key areas where habitats may significantly reduce the economic damage from flooding warrant further investigation to better understand their environmental and economic contributions to flood mitigation and how they should be effectively managed. Notably, regions estimated to provide over £1 million per annum in flood risk benefits include Port Talbot, Swansea, Newport, Neath, the Carmarthen Bay area, and the north coast between Rhyl and the River Dee.
- Exploring the range of flood risk benefits by habitats across Wales, from substantial to limited, could reveal opportunities for targeted habitat management and the implementation of nature-based solutions. This could involve the protection or enhancement of habitats already delivering substantial or moderate flood mitigation benefits, and the restoration or development of underperforming habitats to improve their effectiveness in reducing flood risk.
- The functional value of habitats was based on currently available evidence on the flood risk potential of habitats and expert judgement. More research and site-specific data should be used to determine how the functional value of habitats relates to a reduction in flood damages.
- Coastal Units could be assessed on a site-by-site basis which would involve factoring in local knowledge and site-specific data. This could include a range of factors, for example considering the physical processes and the position of a man-made flood defence relative to the habitats. In addition, habitat condition will play an important role in determining the flood risk benefit of a habitat. Where possible, data on the condition of the habitats should be collected when undertaking local-scale analysis. Site-specific surveys may be useful to validate the data used in this project by verifying habitat characteristics and assessing the location and value of relevant assets.
- Whilst this assessment captured the condition of flood defences, future work could utilise these data to better inform the role habitat situated in front of a defence, plays in reducing flood risk and erosion.
- It is acknowledged that saltmarsh acts differently on the open coast and in estuaries. Future assessments could consider assessing estuarine and coastal saltmarsh separately in a hybrid-approach.
- The primary focus of the current assessment was on how habitats have the potential to reduce flood damage. Future research could also explore the impact on erosion rates.

- The ecosystem accounting results could be undertaken at a regional scale to allow for an interpretation of regional trends to explore which assets are most reliant on habitat protection in different regions.
- Damages to properties could be refined by utilising property-specific damage costs that link to the National Receptor Database, which would allow for disaggregation of the size and age of residential properties and the activities of commercial properties protected by habitats from flooding.
- Agricultural impacts could be further developed to account for the additional costs associated with saline flooding.
- Rail calculations could be refined through working more closely with Network Rail to establish more precise estimates of the impact of flooding in specific locations to rail service cancellations as well as calculating the impact of service delays.
- Road disruption costs could be improved through a spatial model involving network analysis to quantify actual diversion routes.
- A review of the economic outputs should be undertaken in the context of the estimated value of flood protection that is provided by manmade defences.

5. Conclusions

This study has provided a starting point for assessing the benefits that coastal habitats provide towards mitigating flood risk from the sea. The results highlight that the economic benefits of these habitats are particularly pronounced in Coastal Units on the south coast surrounding Port Talbot, Swansea, Newport as well as around Carmarthen Bay and on the north coast around Rhyl and the River Dee. However, it is useful to consider the range of flood risk benefits provided by habitats across Wales, to identify potential opportunities for targeted habitat management and the implementation of nature-based solutions. Maintaining the condition and extent of high functional value coastal habitats is still important for lower economic value coastal units, to avoid future defence requirements or loss of assets: for example, the coastal units at Aberdovey and Tywyn.

As the project was focussed on the national-scale level, further work would be necessary at the local site level through targeted case studies in order to generate more accurate results for each Coastal Unit. This could include factoring in the above recommendations, to provide a more comprehensive database of coastal habitat characteristics and their potential flood risk benefit around Wales.

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7. Appendices

Attribute definitions

To interpret the GIS deliverables, it is useful to understand the attributes and their definitions. Below are column headers with an associated definition.

Attribute name	Definition
CU_ID	The Coastal Unit ID, numbered 1 to 380
AS_GUID	Accommodation Space Global Unique ID, used to create each Coastal Unit by linking this ID to the associated Assessment Unit(s) and Foreshore Area(s)
SM_name	Saltmarsh name
SM_area_m2	Area of saltmarsh within each Coastal Unit in metres squared
SM_l_prop	Proportion of Coastal Unit coastline protected/fronted by the saltmarsh
SM_width_m	Saltmarsh width in metres, estimated by dividing the area by estimated length of coastline protected
DU_name	Dune name
DU_area_m2	Area of dune within Coastal Unit in metres squared
DU_l_prop	Proportion of Coastal Unit coastline protected/fronted by the dune
DU_width_m	Dune width in metres, estimated by dividing the area by estimated length of coastline protected
DU_h_HAT	Dune height above Highest Astronomical Tide (HAT) in metres
SH_name	Shingle name
SH_area_m2	Area of shingle within each Coastal Unit in metres squared
SH_l_prop	Proportion of Coastal Unit coastline protected/fronted by the shingle
SH_h_HAT	Shingle height above Highest Astronomical Tide (HAT) in metres
SM_FV	Saltmarsh Functional Value score
SM_RiD	% Reduction in Damage relating to the FV score for saltmarsh
SM_RiD_len	% Reduction in Damage after adjustment for length for saltmarsh
DU_FV	Dune Functional Value score

Attribute name	Definition
DU_RiD	% Reduction in Damage relating to the FV score for dunes
DU_RiD_len	% Reduction in Damage after adjustment for length for dunes
SH_FV	Shingle Functional Value score
SH_RiD	% Reduction in Damage relating to the FV score for shingle
SH_RiD_len	% Reduction in Damage after adjustment for length for shingle
CU_RiD	The sum of the adjusted Reduction in Damage of all habitats within the Coastal Unit
CU_RiD_adj	The sum of the adjusted Reduction in Damage of all habitats within the Coastal Unit capped at 100%
PR_GBP_yr	Property avoided damage cost total central estimate in Great British Pounds per year
PR_IL	Property Impact Level is the avoided damage cost total central estimate categorised into Very Low, Low, Medium, High, or Very High
AG_GBP_yr	Agricultural Land avoided agricultural output losses total central estimate in Great British Pounds per year
AG_IL	Agricultural Land Impact Level is the avoided agricultural output losses total central estimate categorised into Very Low, Low, Medium, High, or Very High
RD_GBP_yr	Road avoided disruption costs total central estimate in Great British Pounds per year
RD_IL	Road Impact Level is the avoided road disruption costs total central estimate categorised into Very Low, Low, Medium, High, or Very High
RL_GBP_yr	Rail avoided cancellation costs total central estimate in Great British Pounds per year
RL_IL	Rail Impact Level is the avoided rail cancellation costs total central estimate categorised into Very Low, Low, Medium, High, or Very High
Tot_GBP_yr	Total avoided damage cost central estimate across all assets in Great British Pounds per year
Tot_IL	Total avoided damage cost central estimate across all assets categorised into Very Low, Low, Medium, High, or Very High
Def_pres	Defence presence, yes or no
Def_con	Condition of the defence if present

Attribute name	Definition
Erosion_ST	Short-term (0–20 yr) erosion rate under in metres under the SMP scenario
SAC	Special Areas of Conservation present in the Coastal Unit
SPA	Special Protection Areas present in the Coastal Unit
SSSI	Sites of Special Scientific Interest present in the Coastal Unit
Ramsar	Ramsar sites present in the Coastal Unit

Data Archive Appendix

Data outputs associated with this project are archived in X:\Flood Risk\Coastal Habitats Flood Risk Benefit on server–based storage at Natural Resources Wales.

The data archive contains:

- A series of GIS layers on which the maps in the report are based. The data processing is detailed in this report,
- An excel file containing the NCA workbook used for the economic analysis.

Metadata for this project is publicly accessible through Natural Resources Wales' Data Discovery Service https://metadata.naturalresources.wales/geonetwork/srv (English version) and https://metadata.cyfoethnaturiol.cymru/geonetwork/cym/ (Welsh Version). The metadata is held as record no NRW_DS161382.

Further copies of this report are available from library@cyfoethnaturiolcymru.gov.uk